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Sand Creek Massacre National Historic Site

Vegetation Classification and Mapping, A report for the Southern Plains Network

Natural Resource Technical Report NPS/SOPN/NRTR—2007/050

ON THE COVER
Sand Creek Massacre National Historic Site: Big Sandy Creek from near the monument.
Photograph by: Stephanie Neid

Sand Creek Massacre National Historic Site

Vegetation Classification and Mapping, A report for the Southern Plains Network

Natural Resource Technical Report NPS/SOPN/NRTR—2007/050

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Knowledge to Go Places

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Executive Summary

Sand Creek Massacre National Historic Site (SAND) is on the high plains of southeastern Colorado in the rain shadow of the Rocky Mountains. It is in north-central Kiowa County, approximately 25 miles from the state border with Kansas. The site occupies 12,500 acres that are authorized by Congress to protect, interpret, memorialize, and commemorate the Sand Creek Massacre of November 29 and 30, 1864. Within the authorized boundary, 1555 acres have been acquired and established. The site is currently not accessible or open to the public.

SAND is roughly bisected by Big Sandy Creek, a sub-irrigated, intermittent stream typical of a sandy Great Plains riparian system. Loamy, level plains of shortgrass prairie and agricultural fields expand away from Big Sandy Creek to the north and east. Sandhills with sand sagebrush shrublands occupy the south and west side of Big Sandy Creek, much of which is in native rangeland. The authorized boundary of SAND surrounding the established boundary is in private ownership, and it is surrounded by dryland agricultural fields and rangeland with sparse development.

As a newly acquired parcel, National Park Service (NPS) Southern Plains Network initiated a vegetation classification and mapping project as one of many on-going projects to gather baseline data to inform land management decisions and planning. Following the protocols of the USGS – NPS Vegetation Mapping Program, the Colorado Natural Heritage Program (CNHP) performed a two-year project to classify and map the vegetation at SAND. The project was initiated in the spring of 2005 with a project planning meeting between CNHP, SAND biologists, and the NPS program botanist. Project planning and logistics were completed during the late spring of 2005, and vegetation data for classification and mapping were collected during late summer of 2005. The vegetation classification, field key, and local plant association descriptions were completed and written during the winter of 2005 - 2006. Accuracy assessment data were collected over the summer of 2006 and assessment of the vegetation map accuracy was completed in the winter of 2006.

CNHP established 31 vegetation plots and 48 additional data collection points within the established SAND boundary to classify and map the vegetation within the authorized SAND boundary. Multivariate ordination and clustering analyses were used to classify the vegetation. As a result, six plant associations of the National Vegetation Classification (NVC) were identified and locally described. To produce the vegetation map, both National Agriculture Imagery Program 1:12,000-scale, true color, digital ortho-imagery acquired in 2006 and the USDA-FSA-APFO Digital Ortho Mosaic for Kiowa County were used in conjunction with field data to identify vegetation signatures. Four additional non-natural mapping units were devised from the plot and observation point data to complete the map. The accuracy of the map was tested using 134 accuracy assessment plots collected across the ten map classes within the established SAND boundary in 2006. After final revisions, the accuracy assessment revealed an overall thematic accuracy of 94%.

The vegetation map produced for this project provides baseline data for resource management decisions. However, it only reflects a snapshot in time. Plant communities are dynamic entities

that can change given changes in environmental parameters. Current land use, such as grazing management and water withdrawal from the Big Sandy Creek aquifers, will influence changes in vegetation over time. Monitoring these changes will facilitate adaptive management of park resources.

Products developed for the Sand Creek Massacre National Historic Site include:

- A *final report*, which includes site description and landscape context, methods, results and discussion, as well as a list of plant species observed over the two field seasons, a dichotomous key to the map units, local descriptions of the plant associations and other vegetation types, and a visual key to the map units;
- A *spatial GIS database* containing spatial data for the vegetation classes, plots, accuracy assessment points, and observation points;
- *Digital photos* from sample plots and other miscellaneous biological resources;
- *Metadata* for all spatial data (Federal Geographic Data Committee-compliant)
- Hard copy *vegetation map*.

Please check the USGS website (http://biology.usgs.gov/npsveg/index.html) for posting of this information.

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Introduction

USGS-NPS Park Vegetation Mapping Program

In 1994, the U.S. Geological Survey (USGS) and National Park Service (NPS) formed a partnership to map the vegetation of National Parks in the United States using the National Vegetation Classification (NVC). The goals of the USGS-NPS Vegetation Mapping Program are to provide baseline ecological data for park resource managers, create data in a regional and national context, and provide opportunities for future inventory, monitoring, and research activities (FGDC 1997, Grossman et al. 1998).

The use of standard national vegetation classification and mapping protocols facilitates effective resource stewardship by ensuring compatibility and widespread use of the information throughout the NPS as well as by other federal and state agencies. These vegetation maps and associated information support a wide variety of resource assessment, park management, and planning needs, and provide a structure for framing and answering critical scientific questions about vegetation communities and their relationship to environmental processes across the landscape.

Sand Creek Massacre National Historic Site Vegetation Mapping Project

The decision to map the vegetation at Sand Creek Massacre National Historic Site (SAND) as part of the U.S. Vegetation Mapping Program was made under the NPS Natural Resources Inventory and Monitoring Guidelines issued in 1992. Under these guidelines, all Park units within the Service are to be mapped using a consistent set of vegetation classification and mapping protocols. As a newly acquired parcel, baseline biological data was needed in order to inform land management decisions and planning; producing a vegetation map is one of many on-going projects to gather baseline data.

In 2005, the NPS Southern Plains Network (SOPN) initiated this project by requesting the Colorado Natural Heritage Program (CNHP) to undertake both the classification and mapping portions of the project. CNHP biologists conducted both stages of fieldwork (initial classification and accuracy assessment), classification of vegetation types, as well as all mapping.

CNHP collected standardized field samples to classify SAND's vegetation types and also to provide data for an accuracy assessment (AA) on the final vegetation map. CNHP, in conjunction with biological staff at the park, also took on the role of aerial photo interpretation and creation of a digital vegetation map. Finally, SAND staff provided logistical and technical support, helped coordinate fieldwork, and reviewed and evaluated draft data.

Objectives were to produce final products consistent with the national program's mandates. These included the following:

Spatial Data

- Aerial photography
- Map classification
- Map classification description and key
- Spatial database of vegetation communities

- Hardcopy maps of vegetation communities
- Metadata for spatial databases
- Complete accuracy assessment of spatial data

Vegetation Information

- Vegetation classification
- Dichotomous field key of vegetation classes
- Formal description for each vegetation class
- Ground photos of vegetation classes
- Field data in database format

Project Scope of Work

The protocols and standards used to map the vegetation at SAND are described in the NPS program documents (USGS-NPS 2006). These are modified slightly in consideration of the smaller size of SAND compared to many other parks in the Service for which the protocols were originally developed. CNHP purchased Kiowa County aerial imagery for the project mapping through the USDA's National Agriculture Imagery Program (NAIP; National Agriculture Imagery Program 2005). Vegetation mapping for SAND occurred within the authorized park boundary, although the majority of field work was performed within the established park boundary (Figure 1). The established park boundary is currently held by NPS while the authorized boundary surrounding the established boundary is in private ownership[1].

The project was initiated in the spring of 2005 with a project planning meeting between CNHP, SAND biologists, and the NPS program botanist in conjunction with a planning meeting for mapping the vegetation at Bent's Old Fort. Project planning and logistics were completed during the late spring of 2005, and vegetation data for classification and mapping were collected during late summer of 2005. The vegetation classification, field key, and local association descriptions were completed during the winter of 2005 - 2006. The AA data were collected over the summer of 2006. The assessment of the map accuracy was completed during the winter of 2006.

Introduction to the National Vegetation Classification (NVC)

The NPS Vegetation Mapping Program uses the U.S. National Vegetation Classification (NVC) as the standard to identify and describe vegetation types within the map boundaries. The National Vegetation Classification (NVC) was initiated in the early 1990's by ecologists in the Science Division of The Nature Conservancy and state natural heritage programs and conservation data centers in collaboration with partners from the academic, conservation, and government sectors. It has subsequently been adopted by the Federal Geographic Data Committee (FGDC) for use by all U.S. federal agencies. The NVC is now managed and maintained by NatureServe in the online database server NatureServe Explorer that provides regular updates to ecological communities in the United States and Canada. The U.S. NVC is

[1] The 105th Congress of the United States authorized the Sand Creek Massacre National Historic Site Study Act on October 6, 1998. Following a site location study the Sand Creek Massacre National Historic Site was authorized with Public Law 106-465, which requires "the National Park Service to acquire from willing sellers enough area to adequately protect, interpret, memorialize, and commemorate the site." Of the proposed 12,500 acre site ("authorized" park boundary), 1555 acres have been acquired; this is the "established" park boundary (NPS 2005).

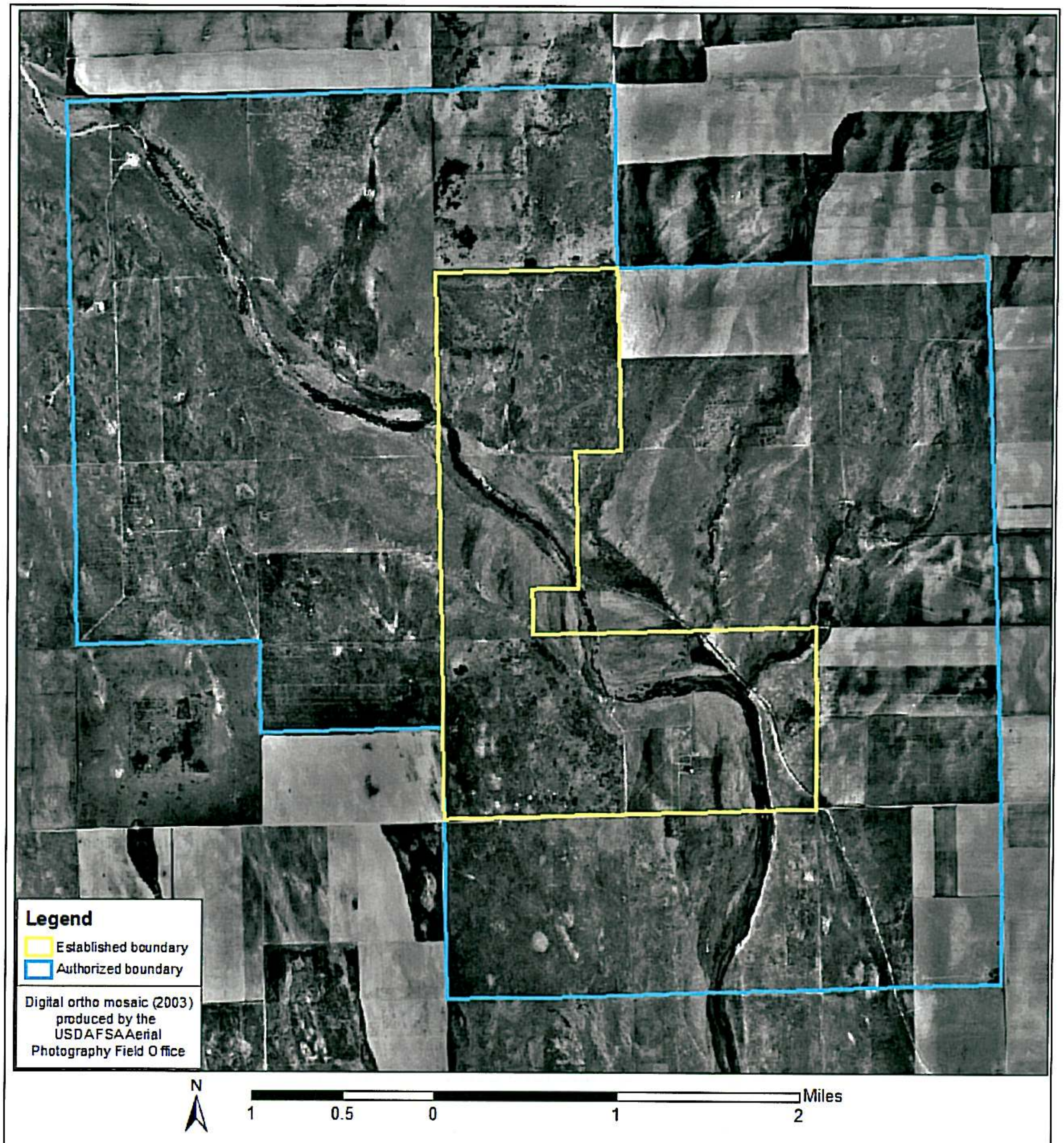

Figure 1. Authorized and established boundaries of SAND.

part of the International Vegetation Classification System (IVC), which currently includes the United States, Canada, and several Caribbean, Central and South American countries.

Basic tenets form the basis of the NVC. It is based upon current vegetation rather than potential natural vegetation, climax vegetation, or physical habitats. It uses a systematic approach to classify continua of vegetation that occur along natural gradients. It emphasizes natural vegetation with less attention to altered or modified types. It also uses a combined physiognomic-floristic hierarchy, identifies vegetation units based on both qualitative and quantitative data, and it is appropriate for mapping at multiple scales. The classification currently includes more than 5600 vegetation associations and more than 1700 alliances (NatureServe Explorer 2006).

The NVC uses a hierarchical system of seven levels; lower, more specific, levels are nested into higher (broader) classification levels. Table 1 identifies the seven levels of the NVC and depicts their placement in the hierarchical relationship (Maybury 1999). The upper five levels of the hierarchy are based on physiognomy (structural and morphological characteristics of the vegetation type, *e.g.* forest, grassland, evergreen, deciduous, broad-leaved, needle-leaved), natural and cultural characteristics, and flood regime. The two lowest levels are alliance and association, which are based on floristics.

Table 1. Summary of the National Vegetation Classification System hierarchal approach (Maybury 1999).

Level	Primary basis for classification	Example
Class	Structure of vegetation	Shrubland
Subclass	Leaf phenology	Evergreen shrubland
Group	Leaf types, corresponding to climate	Microphyllous evergreen shrubland
Subgroup	Relative human impact (natural/semi-natural, or cultural)	Natural/Semi-natural microphyllous evergreen shrubland
Formation	Additional physiognomic and environmental factors, including hydrology	Lowland microphyllous evergreen shrubland
Alliance	Dominant/diagnostic species of the uppermost or dominant stratum	Sand Sagebrush Shrubland Alliance
Association	Additional dominant/diagnostic species from any strata	Sand Sagebrush / Sand Bluestem Shrubland

Alliances and associations are based on both the dominant species in the upper strata of a stand as well as on diagnostic species. Dominant species are those that exhibit the greatest abundance and diagnostic species are those that are consistently found in some types but not others. Associations are the most specific classification and are hierarchically subsumed in the alliances; each association is included in only one alliance, while each alliance typically includes many associations. Alliance names are generally based on the dominant/diagnostic species in the uppermost stratum of the vegetation. Associations define a distinct plant composition which repeats across the landscape and are generally named using both the dominant species in the uppermost stratum of the vegetation and one or more dominant species in lower strata, or a diagnostic species in any stratum. The species nomenclature for all alliances and associations follows that of Kartesz (1999). Naming and syntax for all NVC names are dictated by the following guidelines (Grossman et al. 1998):

- A hyphen ("-") separates names of species occurring in the same stratum.
- A slash ("/") separates names of species occurring in different strata.
- Species that occur in the uppermost stratum are listed first, followed successively by those in lower strata.

- Order of species names generally reflects decreasing levels of dominance, constancy, or indicator value.
- Parentheses around a species name indicates the species is less consistently found either in all associations of an alliance, or in all occurrences of an association.
- Alliance names also include the class in which they are classified (e.g., "Forest," "Woodland," "Herbaceous"), but are followed by the word "Alliance" to distinguish them from associations.
- Association names include the dominant species of the significant strata, followed by the class in which they are classified (e.g., "Forest," "Woodland," or "Herbaceous Vegetation").

Examples of alliance names from SAND:

- *Artemisia filifolia* Shrubland Alliance
- *Populus deltoides* Temporarily Flooded Woodland Alliance
- *Schoenoplectus pungens* Semipermanently Flooded Herbaceous Alliance

Examples of association names from SAND in the respective alliance:

- *Artemisia filifolia / Andropogon hallii* Shrubland
- *Populus deltoides / Pascopyrum smithii - Panicum virgatum* Woodland
- *Schoenoplectus pungens* Herbaceous Vegetation

For more information on the NVC see Grossman et al. (1998).

Introduction to Natural Heritage Program Methodology and Element Ranking

The Colorado Natural Heritage Program (CNHP) is a member of the NatureServe network of natural heritage programs and conservation data centers. The natural heritage programs are located in all the states (and conservation data centers are in all Canadian provinces as well as in several countries in Central and South America). Each program serves as that state's (area's) biological diversity data center, gathering information and field observations to help develop national and statewide conservation priorities.

The multi-disciplinary team of scientists, planners, and information managers at the heritage programs use a standardized methodology to gather information on the rare, threatened, and endangered species and significant natural plant communities that occur in each state. Each program maintains data for species and plant communities that are referred to as "elements of natural diversity" or simply "elements". Life history, status, and locational data are regularly updated in a comprehensive, shared data system. Sources of element data include published and unpublished literature, museum and herbaria labels, and field surveys conducted by knowledgeable naturalists, experts, agency personnel, and our own staff of botanists, ecologists, and zoologists.

The Natural Heritage Ranking System

The cornerstone of Natural Heritage methodology is the use of a standardized element imperilment ranking system. Ranking species and ecological communities according to their imperilment status provides guidance for where Natural Heritage Programs should focus their information-gathering activities and provides data users with a concise and meaningful tool for decision-making.

To determine the status of an element within Colorado, CNHP gathers information on plants, animals, and plant communities. Each of these elements of natural diversity is assigned a rank that indicates its relative degree of imperilment on a five-point scale (1 = critically imperiled, 5 = demonstrably secure). The criteria used to define the element imperilment rank are number of occurrences, size of populations, and overall quality of the populations. The primary criterion is the number of occurrences (in other words, the number of known distinct localities or populations). This factor is weighted more heavily than other factors because an element found in one place is more imperiled than something found in twenty-one places. Also of importance are the size of the geographic range, the number of individuals, the trends in both population and distribution, identifiable threats, and the number of protected occurrences.

Element imperilment ranks are assigned both in terms of the element's degree of imperilment within Colorado (its State-rank or S-rank) and the element's imperilment over its entire range (its Global-rank or G-rank). Taken together, these two ranks indicate the degree of imperilment of an element. For example, the lynx, which is thought to be secure in northern North America but is known from less than five current locations in Colorado, is ranked G5 S1 (globally-secure, but critically imperiled in this state). The Rocky Mountain Columbine, which is known only in Colorado from about 30 locations, is ranked a G3 S3 (vulnerable both in the state and globally, since it only occurs in Colorado and then in small numbers). Further, a tiger beetle that is only known from one location in the world at the Great Sand Dunes National Park and Preserve is ranked G1 S1 (critically imperiled both in the state and globally, because it exists in a single location). CNHP actively collects, maps, and electronically processes specific occurrence information for animal and plant species considered extremely imperiled to vulnerable in the state (S1 - S3). Certain elements are "watchlisted," meaning that specific occurrence data are periodically analyzed to determine whether more active tracking is warranted. A complete description of each of the Natural Heritage ranks is provided in Table 2.

This single rank system works readily for all elements except migratory animal species. Those animals that migrate may spend only a portion of their life cycles within the state. In these cases, it is necessary to distinguish between breeding, non-breeding, and resident species. As noted in Table 2, ranks followed by a "B," for example S1B, indicate that the rank applies only to the status of breeding occurrences. Similarly, ranks followed by an "N" refer to non-breeding status, typically during migration and winter. Elements without this notation are believed to be year-round residents within the state.

Legal Designations for Rare Species

Natural Heritage imperilment ranks should not be interpreted as legal designations. Although most species protected under state or federal endangered species laws are extremely rare, not all rare species receive legal protection. Legal status is designated by either the U.S. Fish and Wildlife Service under the Endangered Species Act, or by the Colorado Division of Wildlife under Colorado Statutes 33-2-105 Article 2. In addition, the U.S. Forest Service recognizes some species as "Sensitive," as does the Bureau of Land Management.

Table 2. Definition of natural heritage imperilment ranks.

Rank	Definition
G/S1	Critically Imperiled globally/state because of rarity (5 or fewer occurrences in the world/state; or 1,000 or fewer individuals), or because some factor of its biology makes it especially vulnerable to extinction.
G/S2	Imperiled globally/state because of rarity (6 to 20 occurrences, or 1,000 to 3,000 individuals), or because other factors demonstrably make it very vulnerable to extinction throughout its range.
G/S3	Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences, or 3,000 to 10,000 individuals).
G/S4	Apparently Secure globally/state, though it may be quite rare in parts of its range, especially at the periphery. Usually more than 100 occurrences and 10,000 individuals.
G/S5	Demonstrably Secure globally/state, though it may be quite rare in parts of its range, especially at the periphery.
G/SX	Presumed Extinct globally, or extirpated within the state.
G#?	Indicates uncertainty about an assigned global rank.
G/SU	Unable to assign rank due to lack of available information.
GQ	Indicates uncertainty about taxonomic status.
G/SH	Historically known, but usually not verified for an extended period of time.
G#T#	Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.
S#B	Refers to the breeding season imperilment of elements that are not residents.
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.
SZ	Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliably identified, mapped, and protected.
SA	Accidental in the state.
SR	Reported to occur in the state but unverified.
S?	Unranked. Some evidence that species may be imperiled, but awaiting formal rarity ranking.

Note: Where two numbers appear in a state or global rank (for example, S2S3), the actual rank of the element is uncertain, but falls within the stated range.

Element Occurrences and their Ranking

Actual locations of elements, whether they are single organisms, populations, or plant communities, are referred to as element occurrences. The element occurrence is considered the most fundamental unit of conservation interest and is at the heart of the Natural Heritage Methodology. To prioritize element occurrences for a given species, an element occurrence rank (EO-Rank) is assigned according to the size, ecological quality and landscape context of the occurrences whenever sufficient information is available. This ranking system is designed to indicate which occurrences are the healthiest and ecologically the most viable, thus focusing conservation efforts where they will be most successful. The EO-Rank is based on three factors:

Size – a measure of the area or abundance of the element's occurrence. This ranking factor takes into account factors such as area of occupancy, population abundance, population density, population fluctuation, and minimum dynamic area (which is the area needed to ensure survival or re-establishment of an element after natural disturbance). This factor for an occurrence is evaluated relative to other known, and/or presumed viable, examples.

Condition/Quality – an integrated measure of the composition, structure, and biotic interactions that characterize the occurrence. This includes measures such as reproduction, age structure, biological composition (such as the presence of exotic versus native species), structure (for example, canopy, understory, and ground cover in a forest community), and biotic interactions (such as levels of competition, predation, and disease).

Landscape Context – an integrated measure of two factors: the dominant environmental regimes and processes that establish and maintain the element, and connectivity. Dominant environmental regimes and processes include herbivory, hydrologic and water chemistry regimes (surface and groundwater), geomorphic processes, climatic regimes (temperature and precipitation), fire regimes, and many kinds of natural disturbances. Connectivity includes such factors as a species having access to habitats and resources needed for life cycle completion, fragmentation of ecological communities and systems, and the ability of the species to respond to environmental change through dispersal, migration, or re-colonization.

Each of these factors is rated on a scale of A through D, with A representing an excellent rank and D representing a poor rank. These ranks for each factor are then averaged to determine an appropriate EO-Rank for the occurrence. If not enough information is available to rank an element occurrence, an EO-Rank of E is assigned. EO-Ranks and their definitions are summarized in Table 3.

Table 3. Element occurrence ranks and their definitions.

Rank	Definition
A	Excellent viability.
B	Good viability
C	Fair viability.
D	Poor viability.
H	Historic: known from historical record, but not verified for an extended period of time.
X	Extirpated (extinct within the state).
E	Extant: the occurrence does exist but not enough information is available to rank.
F	Failed to find: the occurrence could not be relocated.

Study Area

Location and Regional Setting

The location and regional setting of SAND is shown in Figure 2. SAND is on the high plains of southeastern Colorado in the rain shadow of the Rocky Mountains. It is in north-central Kiowa County near the border with Cheyenne County. These counties are both on the state line bordering Kansas. SAND is about 15 miles northeast of Eads and seven miles north of Chivington on County Road W. It is currently not accessible or open to the public. The driveway into the property accesses a homestead site near a defunct airstrip. The road changes to a two-track sand/dirt road that accesses a monument to the Sand Creek Massacre of November 29 and 30, 1864. Another fork of the road goes north to Big Sandy Creek and follows it for approximately two miles within the established park boundary. The authorized boundary of SAND surrounding the established boundary is in private ownership, and it is surrounded by dryland agricultural fields and rangeland with sparse development.

Climate and Weather

SAND is within the Temperate Steppe Division of the Central Shortgrass Prairie ecoregion (Bailey 1994), which is characterized by a semiarid, continental climate where evaporation exceeds precipitation. Winters are cold and dry and summers tend to be hot. Average annual temperatures range between 49.2°F to 56.1°F. Average daily low and high seasonal temperatures are 16.4-46.3°F in winter, 35.3-67.0°F in spring, 58.2-89.7°F in summer and 36.7-69.5°F in the fall. Highest temperatures on average occurring in July and August; average monthly temperatures during these months exceed 90°F with a record high temperature of 110°F. Average minimum monthly temperatures are lowest in December and January; -29°F is the record low temperature. Average annual precipitation is 14.87 inches with snowfall comprising an average of 18.6 inches annually (High Plains Regional Climate Center 2006). A majority of precipitation occurs as thunderstorms in the late spring and mid-summer. By 2005, southeastern Colorado was emerging from several years of drought where drought indices were the most severe within the last century (National Climate Data Center 2006, Rondeau 2003). Conditions of below average precipitation began in the fall of 2000 and did not begin to ameliorate until 2004.

Geology

Surficial geology of SAND, as with much of Colorado's eastern plains, is relatively recent; it is dominated by Quaternary deposits with pockets of late Cretaceous layers (Coffin 1967). Underlying this recent surface is a half billion years worth of accumulated marine sediments and capped with sediments and aeolian deposits. Thousands of feet of marine layers were deposited when the continental interior was under an extensive, shallow, inland sea (Paleozoic to Mesozoic; 570-70 million years ago); these layers were piled atop ancient bedrock that is among the oldest in the continent. The vast inland sea was drained by continental uplift and climate changes, exposing the expansive, nearly flat surface of the former sea floor to weathering and erosion (Trimble 1980).

Continental uplift and volcanism created mountain ranges to the west and successive periods of deposition and aggradation followed. Erosion of the mountain ranges during the Miocene and Oligocene (Tertiary Period, 30-20 million years ago) created an apron of deposits from east-

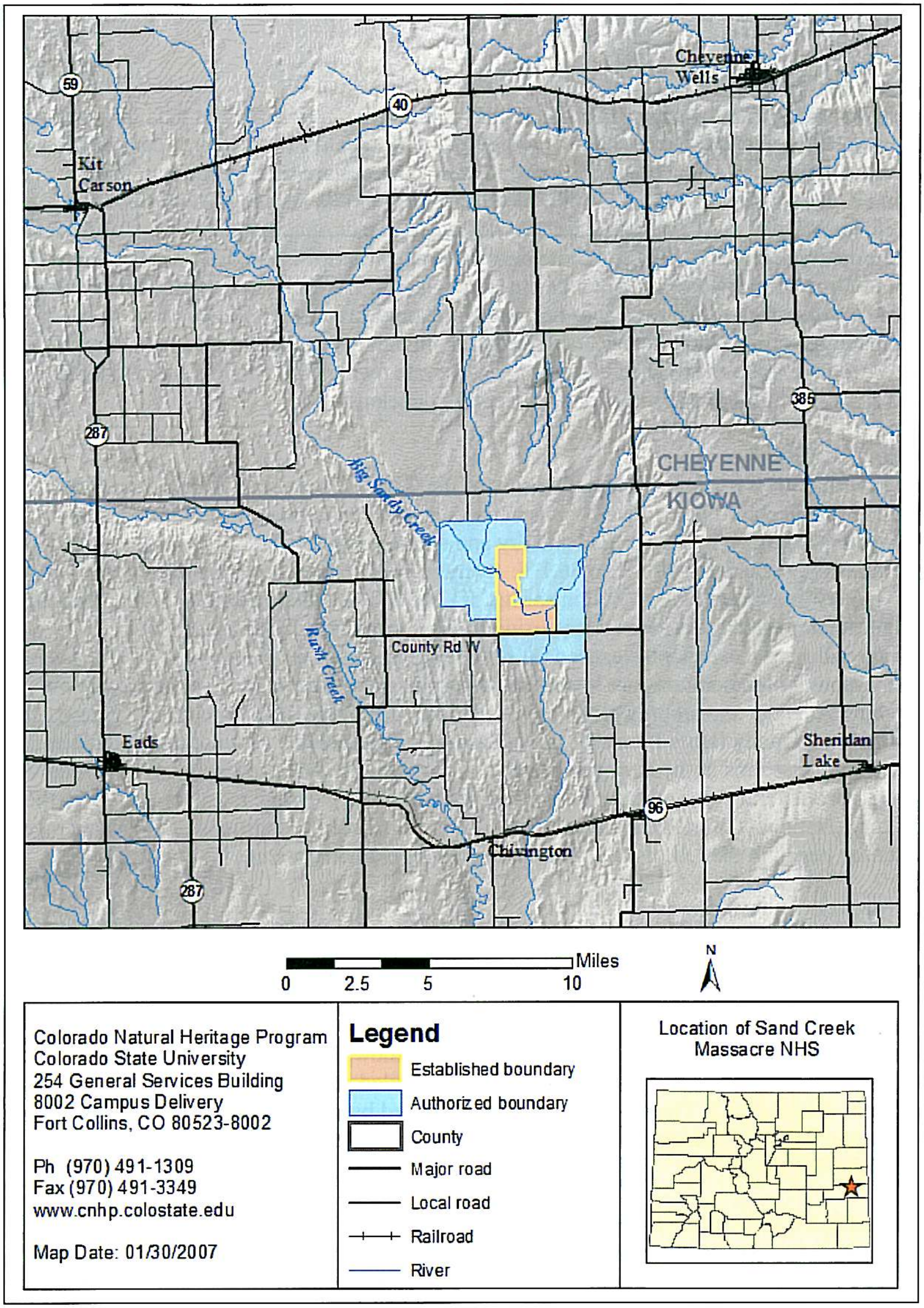

Figure 2. Regional setting of SAND site.

facing drainages that fanned farther out onto the plains as uplift continued (Lugn 1967). These deposits created the Ogallala Formation, which is a heterogeneous group of sandstones derived from alluvial sediments that covered wide paleovalleys of ancient drainage systems (Swinehart and Diffendel 1990). These deposits accumulated in channels, as alluvial fans, and across low relief plains. Much of the Ogallala Formation was scoured away by northwesterly winds that sent particles east- and southeastward over the Piedmont and Plains reworking them into sporadic sand dunes and loess ridges (Trimble 1980), one of which occurs in the vicinity of SAND (Ahlbrant et al. 1983, Tweto 1979). Five to ten million years ago, continental uplift to the west switched the once depositional processes of drainages coming out of the mountains to erosional processes and the South Platte and Arkansas rivers began to incise the plains with broad river valleys.

Recent geologic history has further altered and augmented the Great Plains landscape, especially with regard to climate conditions. Quaternary climate fluctuations have left marked geomorphological changes on the landscape, e.g. glaciation during the last ice age. Several periods of drought have been documented with consequent formation of inland sand dunes. In the last 8000 years there have been abruptly alternating cycles of wet periods followed by arid periods (Swinehart and Diffendal1990, Ahlbrant et al. 1983, Schultz and Hillerud 1978, Lugn 1962). The cyclical alternation created conditions that favored deposition and erosion, respectively. During arid periods, dieback of vegetation exposes soil to wind. These dynamics are evident in riparian drainages where series of deposition and erosion create a sequence of terraces that are distinguishable by their different sediment characteristics (Holmes and McFaul 1999, May and Holen 1985, Schultz and Stout 1977).

Surficial geology within immediate environs of SAND is from the Late Cretaceous and Quaternary periods (Coffin 1967, Tweto 1979). The spatial juxtaposition of bedrock geology is shown in Figure 3. The Late Cretaceous layers are found to the east and northeast of Big Sandy Creek and are comprised of the Smoky Hill Shale member of the Niobrara Formation. Smoky Hill Shale is a dark gray to light gray, very fissile, calcareous shale with a maximum thickness of 4300 feet (1310 m). It has limited exposure in small outcrops throughout the area including the bluff overlooking Big Sandy Creek (Coffin 1967). To the south and west of Big Sandy Creek is Quaternary dune sand, which is comprised of approximately 75% very fine to medium sand and 25% coarse sand. Formed by northwesterly winds, the dune field roughly exhibits a northwest to southeast orientation. The riparian corridor of Big Sandy Creek and its tributaries is comprised of Quaternary alluvium deposits that have undergone successive deposition and erosion and consist of fine-grained elements from Niobrara Formation, loess, and dune sand as well as elements of igneous and metamorphic rocks from farther west. There are at least four terraces identified above the floodplain of Big Sandy Creek (Holmes and McFaul 1999, Coffin 1967). The modern floodplain deposits are embedded within more recent valley-fill deposits that reflect three terraces dating to deposition within the past 2500+ years. These more recent terraces overlie an ancient paleovalley. Much of the ancient terrace geomorphology is covered by dune sand, especially south to adjacent Rush Creek (Coffin 1967).

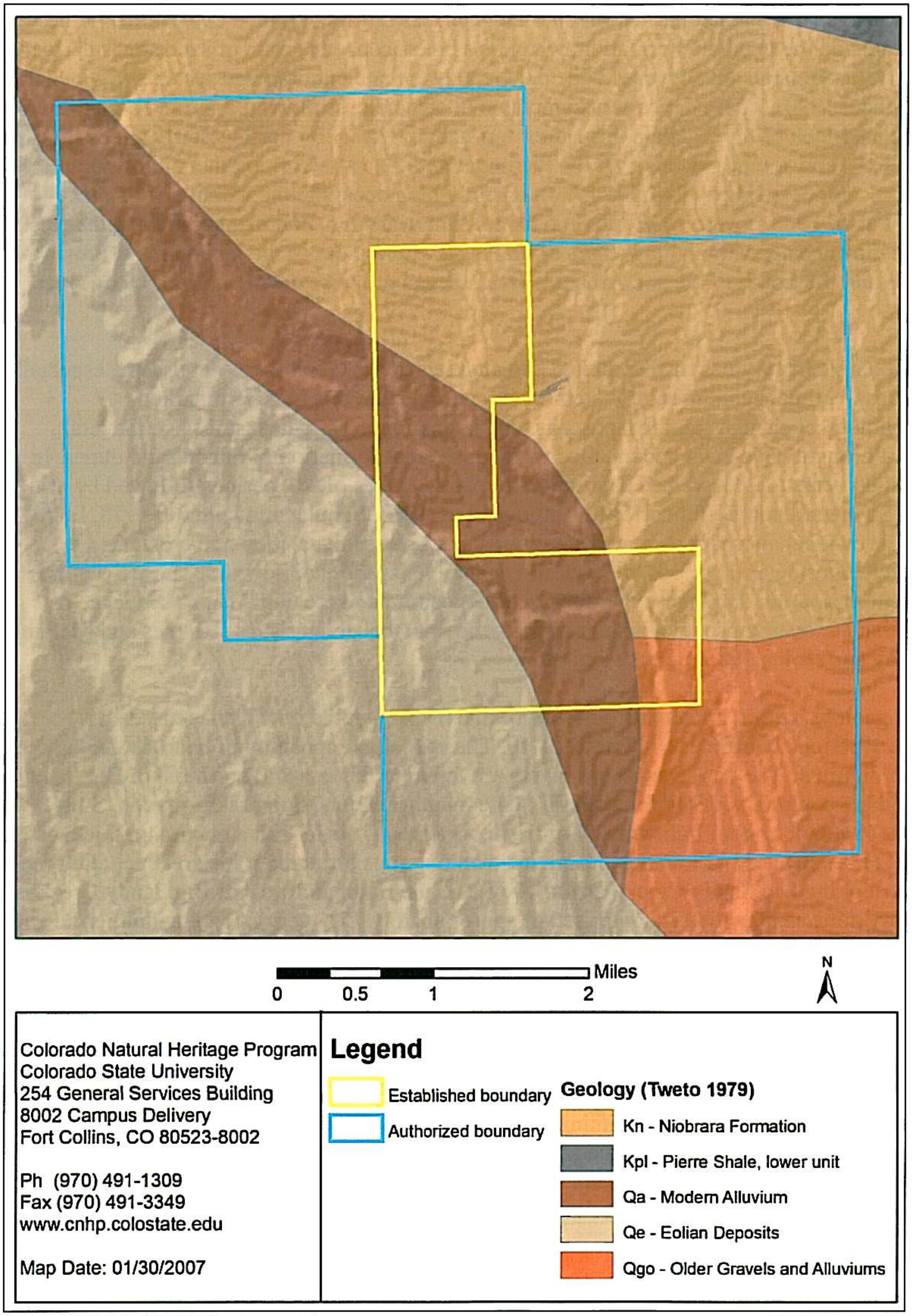

Figure 3. Geology of SAND Site.

Topography

General topography within the authorized SAND boundary is shown in Figure 4. SAND is within the High Plains near where it meets the southeastern periphery of the Colorado Piedmont sections within the Great Plains province (Chapman et al. 2006). SAND falls within Rolling Sand Plains and Flat to Rolling Plains Subsections, which are gently undulating hills comprised of vegetation-stabilized sand plains and dunes derived from aeolian deposits and smooth plains (Figure 5). SAND is roughly bisected by Big Sandy Creek. Loamy, level plains expand away from Big Sandy Creek to the north and east. Sandhills occupy the south and west side of Big Sandy Creek forming a more irregular surface. Oriented in a northwest to southeasterly direction, hill and swale micro topography adds surface complexity and less coherent drainage patterns in this area. The sandhills terminate in a mildly sinuous bluff overlooking the outside bend of ancient terraces of the Big Sandy Creek floodplain. There is a series of three successive terraces above the modern stream channel at 0.5, 1, and 1.5 meters, respectively (Holmes and McFaul 1999). Tributaries of Big Sandy Creek flow in from the north and east side of the sub watershed (HUC12), where side channels have carved through the relatively level plains. Side drainages on the north side within SAND are interrupted by the man-made Chivington Ditch that roughly parallels the creek in the southern half of the established SAND boundary.

Soils

In this region of the temperate shortgrass steppe, calcification is the predominant soil forming process (Bailey et al. 1994). Soils tend to be rich in base ions and have an excess of precipitated calcium carbonate because climate conditions are too dry to leach the ions from the top horizons. Soils are typically mollisols although with relatively low organic matter content due to relatively sparse vegetation of the shortgrass steppe. Salinization occurs in poorly drained areas where evaporation brings salts to the surface (Chapman et al. 2006). Examples of such salinization occur in the small, localized bare spots in swales in the sandhills on the southwest side of SAND.

Soils at SAND are distinctly different on either side of Big Sandy Creek (Figure 6). They are generally categorized as loamy to the north and east of the drainage on gently rolling upland plains and sandy to the south and west where they blanket ancient sandhills (Anderson et al. 1981). In bottomlands along Big Sandy Creek, fluvaqent soils form a mixed mosaic with sands and loams that developed from a mix of alluvial and aeolian deposits in a series of ancient alluvial terraces.

Loamy soils at SAND have developed in loess parent material, which is comprised of wind-blown deposits of predominantly fine-textured materials. Soil types north and east of Big Sandy Creek are fine-textured loams, such as Baca clay loam, Wiley silt loam, and Colby silt loam (Anderson et al. 1981). These are relatively deep, well-drained soils on smooth, rolling plains with gentle slopes (0-3%). They are mostly calcareous throughout and have low organic matter content. These soils are susceptible to wind erosion; there are many eroded areas within the authorized SAND boundary (especially in the northeast corner) within soils mapped as Colby silt loam (Anderson et al. 1981). Native vegetation in these soils is comprised of shortgrass species like blue grama (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), sideoats grama (*Bouteloua curtipendula*), and galleta (*Pleuraphis jamesii*).

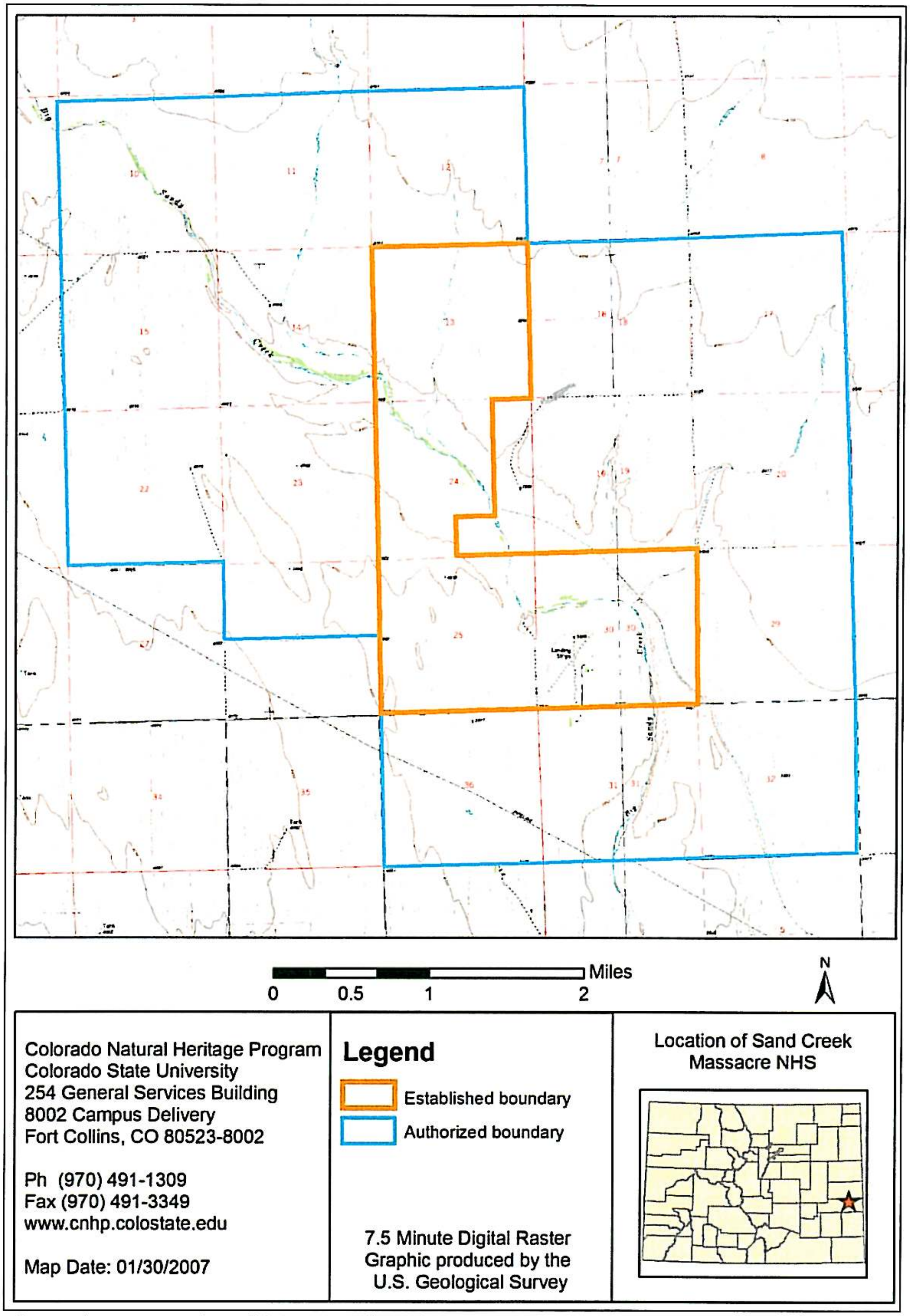

Figure 4. Topography of SAND and environs.

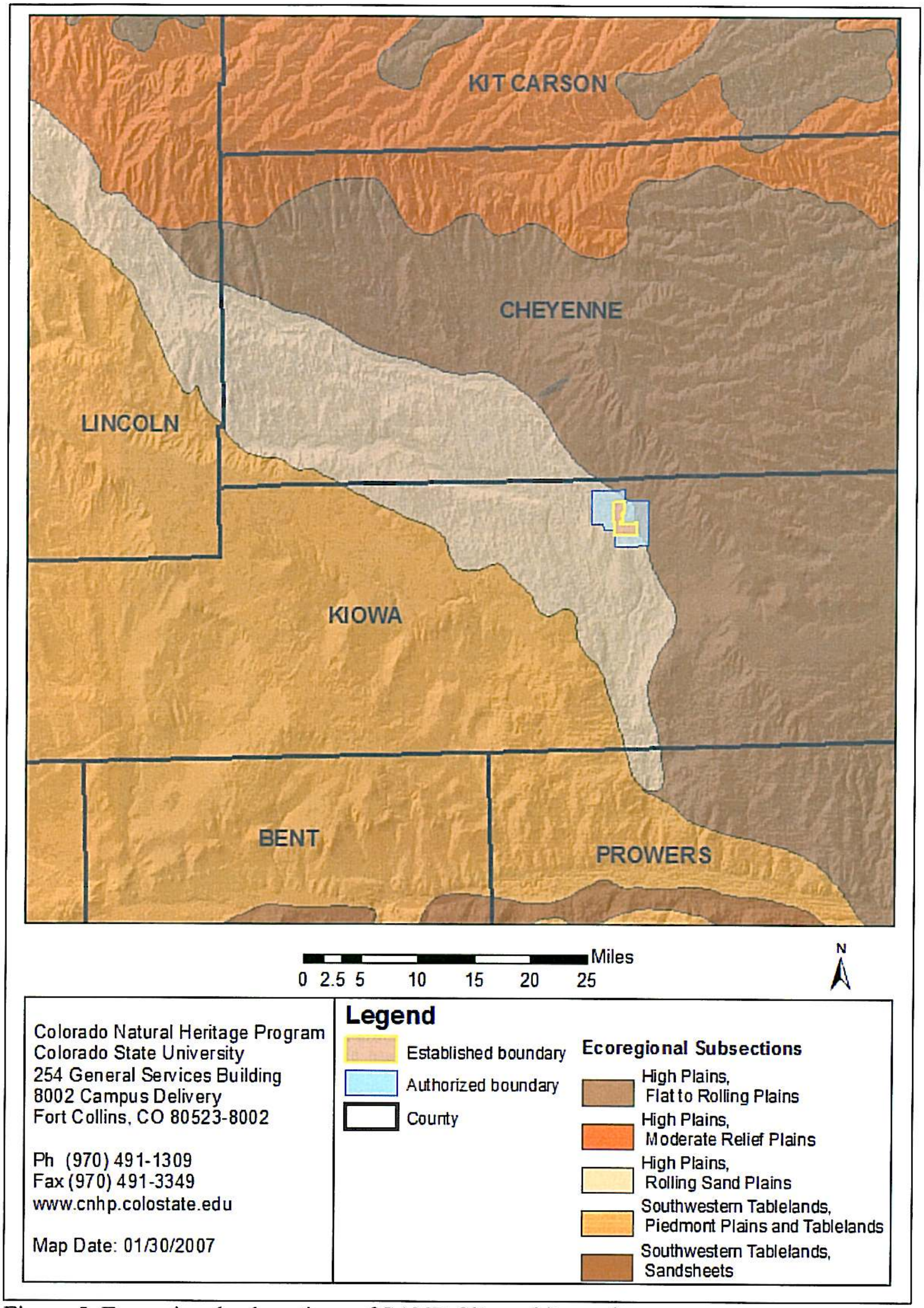

Figure 5. Ecoregional subsections of SAND Site and its environs.

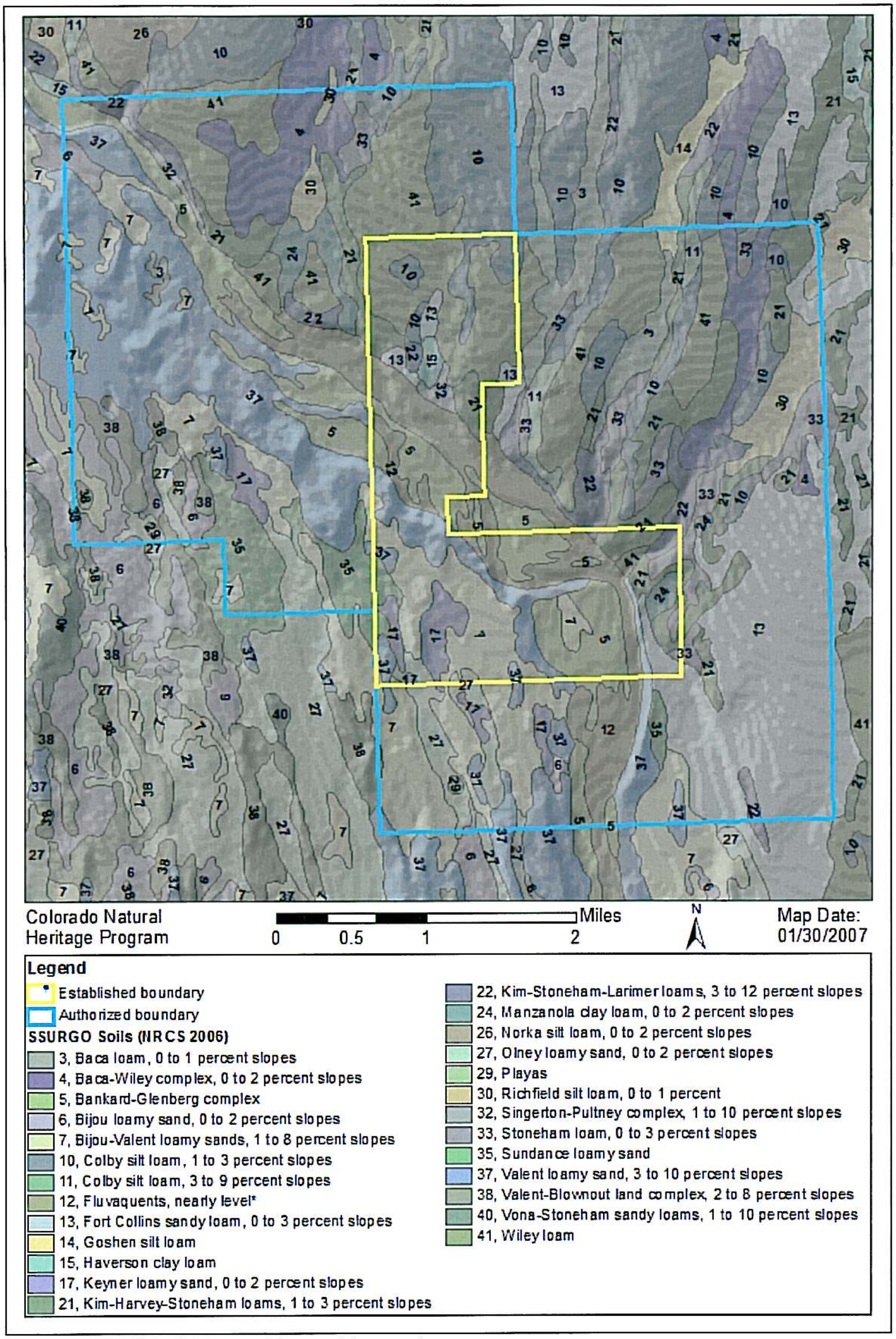

Figure 6. Soils of SAND Site and its environs.

Sandy soils to the south and west of Big Sandy Creek have developed over sand parent material. The sandhills overlain by these soils have more complex micro topographic features. The undulating surface is more variable with less well-defined drainage patterns and shorter, more complex slopes that range from 0 to 17%. Micro topography in this area has considerable hill and swale morphology. Soil types thus are a mosaic of different loamy sands; types include Bijou, Valent, Keyner, Olney, and Sundance (Anderson et al. 1981). Valent soils dominate the ridges and knolls whereas Bijou occurs on gentler sideslopes. Keyner and Olney have developed in the local low lying swales in the sandhills. As eolian depositional areas, these consequently have finer-textured subsoils. Keyner loamy sand differs from Olney loamy sand in that it has saline and alkaline components, which are lacking in Olney soils. Sundance soils are still loamy sand, but are considered transitional to the loamy soils found to the north of Big Sandy Creek. These sandy soils have a very high susceptibility to wind erosion; management concerns are primarily devised to prevent blowouts. Native vegetation in these sandy soils has a strong component of tallgrass species such as sand bluestem (*Andropogon hallii*), sand reed (*Calamovilfa longifolia*), sand muhly (*Muhlenbergia arenicola*), and switchgrass (*Panicum virgatum*) as well as short and midgrass species such as blue grama and sideoats grama. Valent soils, the sandiest and most arid of the group, have sand sagebrush (*Artemisia filifolia*).

The Big Sandy Creek drainage separates areas of sandy soils from areas of loamy soils. The drainage valley is composed of the modern stream channel that flows beneath a series of terraces that comprise the ancient floodplain (Holmes and McFaul 1999, Coffin 1967). Soils in this corridor are a mosaic of Bankard fine sandy loam and Glenberg loamy sand on the floodplain terraces interspersed with fluvaquents. The fluvaquents, which have a highly variable textural composition and thickness, generally define the current stream channel although they also form large patches within the terraces on SAND in certain places. A common feature of all soil types in the floodplains are stratified, thin layers of contrasting texture interbedded at various depths, which is not unexpected in an alluvial setting. The distinguishing feature of fluvaquent soils is the relatively shallow depth to the seasonally high water table. The water table is one to three feet below the surface on average in the spring (Anderson et al. 1981). Although variable, surface soil is often clay loam over mottled, stratified materials that range from clay to sand to gravel. Native vegetation within the channel is characterized by alkali sacaton (*Sporobolus airoides*), inland saltgrass (*Distichlis spicata*), switchgrass, western wheatgrass, indiangrass (*Sorghastrum nutans*), and alkali muhly (*Muhlenbergia asperifolia*).

The modern terrace soils adjacent to and above the stream channel have developed atop ancient terraces. Bankard soils are sandier than Glenberg and are loamy fine sand over loamy sand. Glenberg soils are fine sandy loam. Embedded within the terrace soil matrix are localized inclusions of soils with clay loam on the surfaces with relatively impeded drainage as well as areas of seasonally high water table (Anderson et al. 1981). Vegetation in these inclusions differs from the general composition on the terraces, which is a mix of short- and tallgrasses with sand sagebrush. Deeper horizons in the terrace soils have lenses and layers of different texture. These terraces have alluvial baselayers that have been covered by aeolian deposition (Holmes and McFaul 1999). Modern or surface soils have developed in aeolian deposits whereas buried layers represent soils that developed from alluvial sediments of the ancient floodplain.

Hydrology

The hydrology of SAND is defined by Big Sandy Creek. The Big Sandy Creek sub-basin (HUC12) is on the northeastern edge of the Upper Arkansas drainage (HUC6) and it encompasses 1871 square miles (4846 km^2). It begins in El Paso County northeast of Colorado Springs and arcs through Elbert, Lincoln, Cheyenne, and Kiowa counties before its confluence with the Arkansas River approximately eight miles downstream from Lamar in Prowers County. It flows through the towns of Ramah, Simla, Limon, Hugo, and Kit Carson before reaching SAND. Side tributaries of Big Sandy, such as Eureka Creek, drain from the east- and northeast. Rush Creek forms the adjacent sub-basin to the south and west of Big Sandy Creek and merges with it south of SAND (see Figure 2).

Big Sandy Creek is a typical intermittent stream of semiarid climates (Labbe and Fausch 2000). There are short reaches where there is perennial flow in Big Sandy Creek including a stretch on SAND where water input from the tributary that bisects the Chivington Ditch from the northeast maintains surface water. Outside of these areas, surface water is contained in small, isolated pools during most of the year. As also is typical of streams in the region, Big Sandy Creek can have a flashy hydrograph in response to brief, heavy rain storms within the watershed. Flooding from localized thunderstorms can be severe, but is generally brief due to rapid absorption in sandy soils (Labbe and Fausch 2000).

The Upper Big Sandy is a groundwater basin in the eastern plains with series of Quaternary alluvium aquifers (Sares et al. 2003). As the underlying Cretaceous bedrock is relatively impermeable, groundwater accumulates in the overlying Quaternary layers. Groundwater recharge through direct infiltration of precipitation and surface flow can occur at 3 acre feet per acre of wetted stream channel (Coffin 1967). Water wells along Big Sandy Creek are concentrated upstream, especially around Ramah, Simla, and Limon (Topper et al. 2003) with greater groundwater utilization occurring over the last sixty years (Labbe and Fausch 2000).

Vegetation

Vegetation at SAND is a mosaic of sand sagebrush shrubland and shortgrass prairie bisected by a corridor of riparian vegetation. Sand sagebrush occupies the sandhills to the south and west of Big Sandy Creek on SAND and shortgrass prairie generally characterizes the loamier north and east side. The riparian corridor is a mosaic of cottonwood woodland, mesic grassland, and wet meadow surrounding a narrow, braided stream channel.

The shortgrass prairie ecological system occurs east of the Rocky Mountains covering much of the eastern plains of Colorado and extending into adjacent states. It generally occurs on flat to rolling terrain and is characterized by short-statured graminoids, such as grama grasses and buffalograss, and with a sporadic but diverse forb component. Occasionally a limited number of shrubs, *e.g.*, sagebrush (*Artemisia* spp.), snakeweed (*Gutierrezia sarothrae*), or yucca (*Yucca glauca*) may punctuate the landscape (Costello 1944). In general, warm season species are more abundant than cool season species. Primary ecological processes that maintain shortgrass prairie are climate (especially precipitation) and grazing. The rainshadow of the Rocky Mountains restricts the amount of precipitation that falls on the plains, creating arid to semiarid conditions. Historically, grazing by roaming bison herds maintained the short stature of the vegetation. Today, grazing by domestic cattle maintains the vegetation structure; although, cattle herds require an established rotational grazing regime to maintain dynamic vegetation patches that reflect the inherent diversity within the system (NRCS 2004a). Fire is less important in this grassland primarily because xeric conditions tend to decrease fuel loads and thus decrease fire frequency. Prairie dogs are a common and crucial component of this system; their colonies provide habitat for a myriad of additional animal species. Drought effects on shortgrass prairie include low production and dieback of vegetation depending on the severity of conditions (Rondeau 2003, Albertson and Weaver 1944).

The sand sagebrush ecological system occurs on somewhat excessively to excessively well-drained, deep, sandy soils and is most often associated with ancient dune systems and ancient floodplains. The system is characterized by a sparse to moderately dense short shrub layer of sand sagebrush over a diverse understory. Sand sagebrush is well-adapted to nutrient-poor soils and seed germination requires open, shallow soils. It re-sprouts vigorously after fire and is less palatable to cattle (McWilliams 2003). The herbaceous understory has abundant graminoids as well as diverse forbs. Graminoid species include tallgrass species such as sand bluestem, sand reed, little bluestem (*Schizachyrium scoparium*), needle and thread (*Hesperostipa comata*), and sideoats grama. Shorter-statured blue grama is generally ubiquitous within the system. Diverse forbs are often present including sandy indicators like othake (*Palafoxia sphacelata*), flatspine burr ragweed (*Ambrosia acanthicarpa*), mountain evening-primrose (*Oenothera latifolia*), western daisy fleabane (*Erigeron bellidiastrum*), Andean prairie clover (*Dalea cylindriceps*), and many others (Clark personal communication 2005, NRCS 2004b, Costello 1944). There is often a relatively high proportion of native annuals in this system, such as annual buckwheat (*Eriogonum annuum*) and prairie sunflower (*Helianthus petiolaris*).

Species composition within sand sagebrush ecological systems responds to various disturbance mechanisms. Forbs and tallgrasses tend to be highly palatable to domestic cattle and will decrease with increased grazing (NRCS 2004b). Both sand sagebrush and blue grama are thought to increase in cover with continuous grazing. Increasing abundance of these species is considered to be an early stage of desertification as the nutrient balance and energy flow provided by greater plant diversity is compromised. The unconsolidated nature of sandy soils makes them especially susceptible to wind erosion. If vegetation cover is insufficient, vegetation is undermined as wind carries away the substrate; this is termed a blowout. Blowouts of a certain size are a natural dynamic in sandhill systems and tend to have blowout grass (*Redfieldia flexuosa*), Schweinitz's flatsedge (*Cyperus schweinitzii*), indian ricegrass (*Oryzopsis hymenoides*), James' clammyweed (*Polanisia jamesii*), and others (Ramaley 1939). Decreased plant vigor and cover from drought or from improper levels of grazing can encourage excessive blowouts, which are not desirable (NRCS 2004b).

The riparian corridor of Big Sandy Creek is typical of an intermittent stream on the Great Plains. It is a linear ecological system that occupies the floodplain and terraces of Big Sandy Creek. These systems are maintained by hydrology, especially surface and subsurface flow. The porous nature of the bedrock surrounding SAND allows water to flow underground in alluvial aquifers. Further, mineralization increases specific conductance of groundwater resources within the Big Sandy Creek sub-basin; groundwater in this sub-basin is classified as a sodium calcium sulfate bicarbonate type (Coffin 1967). Thus the wet meadow vegetation along Big Sandy Creek has salinity indicator species such as alkali sacaton and inland saltgrass (Anderson et al. 1981). This riparian system is a mosaic of riparian woodland canopy, wet meadow, and wetlands.

Wildlife

SAND provides a small oasis of shortgrass prairie habitat that is surrounded by agricultural fields and sand sagebrush rangeland. It is habitat for a wide diversity of wildlife associated with shortgrass prairie, such as black-tailed prairie dogs (*Cynomys ludovicianus ludovicianus*), shortgrass prairie birds, raptors, and pronghorn (*Antelocapra americana*) (Sovell 2006) and for more generalist wildlife species such as mule deer (*Odocoileus hemionus*). The region also has an established population of non-native, feral hogs (*Sus scrofa*), (Hartman 2006).

Of the wildlife species at SAND, prairie dogs have the greatest influence on vegetation. Black-tailed prairie dog towns historically covered millions of acres within the Great Plains, especially in the shortgrass prairie. Prairie dogs dig extensive burrow systems in their towns. They graze the surrounding vegetation, keeping it clipped short, creating the appearance of a mowed lawn, or heavily grazed rangeland. This behavior is presumably to improve their ability to detect predators. Preferential grazing alters plant species composition within a few years after colonization (Hoagland 1995). While plant cover decreases overall, annual forbs become more abundant due to increased small-scale disturbance from digging. Prairie dog towns can expand and contract over time as prairie dog populations fluctuate. Their towns, however, provide habitat for a wide diversity of animal species that utilize them, such as badgers (*Taxidea taxus*), eastern cottontails (*Sylvilagus floridanus*), coyotes (*Canis latrans*), grasshopper mice (*Onychomys leucogaster*), swift fox (*Vulpes velox*), pronghorn antelope, striped skunks (*Mephitis mephitis*), white-tailed deer (*Odocoileus virginianus*), cattle, thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*), black-tailed jackrabbits (*Lepus califonicus*), barred tiger salamanders (*Ambystoma tigrinum*), plains spadefoot toads (*Scaphiopus bombifrons*), Great Plains toad (*Bufo cognatus*), Woodhouse's toad (*Bufo woodhousii*), prairie rattlesnakes (*Crotalis viridis*), western plains garter snakes (*Thamnophis radix*), Texas horned lizards (*Phrynosoma cornutum*), ornate box turtles (*Terrapene ornata*) (Lomolino and Smith 2003), and other shortgrass prairie birds (Smith and Lomolino 2003). Prairie dog towns also attract aerial predators such as hawks, eagles, and falcons. Prairie dogs towns occur on much of the shortgrass prairie within the authorized SAND boundary.

Methods

Preliminary Data Collection and Review of Existing Information

To establish a preliminary list of associations, ecologists queried the NatureServe Biotics database for the types known to occur within the Central Shortgrass Prairie ecoregion (Central Shortgrass Prairie Ecoregional Planning Team 1998). Based on that query the preliminary list contained 62 associations.

Field Survey

The field survey of vegetation associations at SAND was conducted by CNHP ecologists during August through September of 2005. CNHP field biologists reviewed the 1998 black and white aerial photos (USDA-FSA-APFO Digital Ortho Mosaic: ortho_e1-1_co061) of the site to identify areas with unique vegetation signatures and traveled over all areas to place vegetation sample plots in each observed vegetation type. Plot locations were subjectively located in homogeneous examples of each vegetation type found in the park using the NPS National Vegetation Mapping Program protocols. Data collected at each plot location included the composition and structure of the vegetation and environmental data (soils, slope, aspect, geology, landform) to conduct the classification and inform the mapping, and fuels data for fire and fuels management. Four photographs of the relevé plot locations were taken, one in each cardinal direction.

General Plot Collection Considerations

Field data collection at SAND was completed by a single crew of two CNHP biologists working in late summer of 2005. The crew was provided with a field manual describing all of the methodology for the plot sampling, as well as supplemental information on sampling techniques, field safety, species lists, and accepted plant species codes. The field manual, including the plot field form, is provided in Appendix A. The crew was also given a list of the 62 preliminary vegetation types to be sampled and was instructed to collect at least one plot in each type, and up to three if the area was significantly large. Because SAND is a small park, all of the vegetation types are relatively easy to access and identify. Sample plots were therefore systematically placed in each vegetation type as it was encountered. This eliminated the need for the more complicated GRADSECT analysis (Gillison and Brewer 1985, Austin and Heyligers 1989) protocol used to identify potential sample sites in large parks. The following is a general description of the process. Using topographic maps and black and white aerial photos of the site, crews were instructed to travel by foot over the site looking for examples of the vegetation types in the preliminary list or any other types not listed. Upon encountering a type for which sufficient samples had not been collected, the crews would locate a sample plot in a representative location within the boundaries of the type. When the plot had been completed, crews would navigate to another suitable plot location in the same or another vegetation type and begin the process again.

Data Collection: Relevé Plots

At each selected sampling location, plot data were collected using NPS National Vegetation Mapping Program protocols (USGS-NPS 2006). Crew members selected the plot center and buried a permanent marker (a small copper tag inscribed with the project acronym, plot code, and date, attached to a galvanized nail) and recorded UTM coordinates from a GPS. They laid out the plot according to the size specified in the field manual for that vegetation type ($400m^2$ plots for woodlands and shrublands or $100m^2$ plots for grasslands). Crews analyzed the vegetation by dividing the vegetation visually into strata, or height classes, and recorded the dominant species by cover in each stratum. They then developed a comprehensive species list for the plot recording species name and percent cover for each plant found within the plot. Species nomenclature follows that of USDA PLANTS database (USDA NRCS 2005).

Numerous other data describing the environmental characteristics of the site were collected at each plot including elevation, slope, aspect, soil texture, surficial geology, percent ground cover, and hydrology. Before breaking down the plot, crews would attempt to identify the plot with one of the potential vegetation type names. If the plot did not fit into an existing vegetation type, crew members were required to assign a new type name based on the dominant species in the top two strata. Four photographs were taken from the plot center of each plot oriented to the cardinal directions.

Data Collection: Forest Fuels Data

Fire management data (fuels data) were collected at each site visited. Fuels data collected included information on both live and dead/down fuels. Live fuels data included the surface cover of shrubs and herbaceous species. For the dead/down fuels, crews recorded cover of coniferous and deciduous leaf litter, woody debris, and unburnables (rock, mineral soil, open water). At plot center and at ten meters from plot center on the cardinal directions, crews also measured the depth of litter and duff. Four photos were taken at each site and photo information was recorded on the fuels datasheet.

Plot Data Management

Following data collection and prior to data entry, duplicates of the field forms were made and stored off site to ensure a duplicate set would always be available. The original plot forms were then checked to ensure quality control (QC) of the collected data. Particular attention was paid to making sure that the recorded plot location was correct and that all relevant fields had data. When information was missing, an effort was made to find and record that information, often from the associated fuels form, or from other data sheets produced by the same crew on that or an adjacent day. Changes to field form entries were made in red pen and marked with a date and the reviewer's initials.

Following the QC of the datasheets, the data were entered into the PLOTS database, and all plots were subjected to a second QC to eliminate any data entry errors. During this second QC, the database was examined, sorted, and queried to find missing data, misspellings, duplicate entries, and typographical errors. The species lists were carefully examined to make sure that only USDA PLANTS names and acronyms (USDA NRCS 2005) were used, and that species names and assignments to strata were consistent and logical. Plant lists were compared to the assigned association name to ensure correlation.

Vegetation Classification

Plot data were analyzed and interpreted with the goal of classifying plots at the association level using species composition and environmental characteristics/parameters. Plot data were exported from PLOTS and formatted as matrices for import into PC-ORD version 4.37, a multivariate statistical software package (McCune and Mefford 1999). Data were explored using summary statistics, outlier analysis, cluster analysis, indicator species analysis (ISA), multi-response permutation procedures (MRPP), two-way indicator species analysis (TWINSPAN), and non-metric multidimensional scaling (NMS) ordination. The intent was to finalize the community classification by incorporating the type concepts that emerged from the park into the NVC, not to create an individual, site-specific classification. Thus these analyses guided the assignment of plots to associations in combination with our ecological understanding of the landscape as well as the additional observation point data collected at the site.

A total of 79 sample plots were collected; there were 31 relevé plots and an additional 48 observation points. The 31 relevé plots were used in the vegetation classification due to their full species lists. The remaining 48 observation points were used to inform final vegetation classes and mapping and to define and describe local types.

For the classification analyses, mid-points of each cover class were used as the absolute cover for the plot data. Species that occurred in only one plot were removed to reduce noise in the dataset. Summary statistics were generated to inform underlying assumptions for the analyses (assessing heterogeneity, skewness, etc.). Outlier analysis was performed to identify any plots that may have disproportionate effects on the analyses; the analysis identified any plots having greater than two standard deviations from the average distance. Cluster Analysis using Sorensen distance and the flexible beta linkage method (ß=-0.25) was performed to identify similar groups within the dataset. Pruning of the resulting cluster dendrogram of plots was directed by ISA (Dufrêne and Legendre 1997) and significant differences between groups were identified using MRPP (McCune and Grace 2002). MRPP tests the hypothesis of no differences between groups without requiring normality or homogeneity of variance and was run using Sorenson distance on cluster groups (McCune and Grace 2002, Zimmerman et al. 1985). Due to the small size and heterogeneous nature of the dataset TWINSPAN was used merely to corroborate patterns in cluster analysis and was run using defined cuts for percentage data in PC-ORD. NMS ordination was run using random starting configuration, Sorenson distance, and forty runs with real data (Mather 1976, Kruskal 1964). Low stress (stress is the inverse measure of the fit of the data according to the environmental parameters analyzed) was sought in the results (McCune and Grace 2002).

Vegetation Mapping

Photo Interpretation, Map Units, and Polygon Attribution

After fieldwork was completed, ecologists used field data (plot data, observation points, photographs, and field notes) and digital aerial imagery (NAIP 2005) to map draft vegetation polygons for SAND within an ESRI personal geodatabase. Vegetation polygons were drawn based on aerial photo signatures and plot and observation point data. Photographs, field notes, and plot data were used to refine visual analysis of aerial photo signatures in order to draw final polygons. Table relationships were used to create a drop-down list of plant associations and map unit categories in the attribute table to ensure consistent data entry. A CNHP GIS Specialist then cleaned the layer topology, removing overlaps, gaps, slivers, and any data inconsistencies. FGDC compliant metadata was created for the vegetation layers and the layers were exported from the geodatabase as ESRI shapefiles. The layers are all in the coordinate system UTM Zone 13, North American Datum 1983.

Map Verification

After completing interpretation of the aerial photography, the polygon line work was reviewed for accuracy. Line work was checked to identify errors in the topology, ensure that polygons were correctly labeled, and to locate any extra or missing lines. The map and map units were then modified to correct any identified errors.

Accuracy Assessment

Sample Method and Design

The protocol used to select the AA sample points is that described by the NPS Vegetation Mapping Program, Accuracy Assessment Procedures manual (USGS-NPS 2006). That protocol's design employs accepted sampling and statistical analysis methods, yet is also intended to be economically and logistically practical.

Map accuracy discussed here, and as prescribed by the above protocol, is concerned strictly with thematic map accuracy. Positional map accuracy, describing the accuracy with which map features are located, is not considered. Because polygon boundaries are rarely explicitly delimited in the field, and therefore subject to interpretation, it is unnecessary and impractical to estimate their accuracy.

The AA protocol uses mapped class abundance and frequency, and defines maximum and minimum sample sizes needed to ensure statistical validity. The sample selection method is a stratified random design, stratified by map units. Based on map class abundance and frequency, five different sample sizes were possible. These are defined in Table 4.

Sample Site Selection – AA Points

Due to a lack of landowner permission to perform field work throughout the authorized boundary, accuracy assessment was only performed on the map within the established boundary. Using the above parameters, we used ESRI ArcMap version 9.0 GIS software in conjunction with the Hawth's tools extension (Beyer 2005) to randomly locate the correct number of sample points within the map polygons. A minimum separation distance between points of 100 meters was chosen for this effort. We also evaluated minimum separation distances of 50m and 150m. It was determined that 100m was the largest separation distance we could use and still be able to place all of the needed points within some of the smaller polygons. This method does not allow the user to specify a minimum distance from the polygon edge, and therefore results in some plots being located on or near to the polygon boundary

We used this method to create two sets of potential AA samples – a primary set and a secondary replacement set. Each set of points was stratified by map class. The primary set was the preferred

Table 4. Recommended map accuracy sample number per class by frequency and area (USGS-NPS 2006).

Scenario	Description	Polygons in class	Area occupied by class	Recommended number of samples in class
Scenario A:	The class is abundant. It covers more than 50 hectares of the total area and consists of at least 30 polygons. In this case, the recommended sample size is 30.	>30	> 50 ha	30
Scenario B:	The class is relatively abundant. It covers more than 50 hectares of the total area but consists of fewer than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size for this type of class is that sample sites are more difficult to find because of the lower frequency of the class.	< 30	> 50 ha	20
Scenario C:	The class is relatively rare. It covers less than 50 hectares of the total area but consists of more than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size is that the class occupies a small area. At the same time, however, the class consists of a considerable number of distinct polygons that are possibly widely distributed. The number of samples therefore remains relatively high because of the high frequency of the class.	> 30	< 50 ha	20
Scenario D:	The class is rare. It has more than 5 but fewer than 30 polygons and covers less than 50 hectares of the area. In this case, the recommended number of samples is 5. The rationale for reducing the sample size is that the class consists of small polygons and the frequency of the polygons is low. Specifying more than 5 sample sites will therefore probably result in multiple sample sites within the same (small) polygon. Collecting 5 sample sites will allow an accuracy estimate to be computed, although it will not be very precise.	.5,.30	<50 ha	5
Scenario E:	The class is very rare. It has fewer than 5 polygons and occupies less than 50 hectares of the total area. In this case, it is recommended that the existence of the class be confirmed by a visit to each sample site. The rationale for the recommendation is that with fewer than 5 sample sites (assuming 1 site per polygon), no estimate of level of confidence can be established for the sample (the existence of the class can only be confirmed through field checking).	< 5	< 50 ha	Visit all and confirm

target for the sample; however, if a target was inaccessible or if the primary sample was too close to the polygon boundary, the crews were instructed to use the first available sample from the secondary set of points. This systematic reselection process maintains the stratified random design for the selection of points and was designed to allow crews to collect a complete set of AA points.

Data Collection – AA Points

Field maps were produced that showed the primary sample point and polygon boundary. The addition of the polygon boundary to the field map aided in navigation to the point and provided the field crews with some contextual information. Field crews navigated to each point using the field maps produced for this effort in addition to a GPS with a known target location.

Upon arrival at a point, the SAND crew began with a broad visual survey of the area. This was done to determine whether vegetation at the point was representative of the map polygon (to identify ecotones or inclusions). If vegetation was not representative, or if the point was too close to the polygon boundary, the crew selected a replacement point from the secondary frame. The crew then visually determined the boundaries of the point to be sampled. The minimum mapping unit was 0.5 ha and this was used as the sample plot. The crew then collected data on species composition, vegetation structure, and geology and topography of the area. After filling out the AA Point form (Appendix B), the crew used the Field Key and local descriptions (Appendix C) to assign a plant association to the plot. If no association seemed to fit, the crew assigned an association name to the plot based on the NVC naming conventions for associations (dominant species of the primary strata). If more than one name seemed to fit, the crews provided a primary and a secondary name. At each plot, four pictures were taken in each of the cardinal directions from the plot center. Further, crews documented what they observed at the plots by recording extensive field notes. Pictures and field notes proved useful in resolving classification questions later during the AA.

Data entry and QC – AA Points

Field sheets for the accuracy assessment were reviewed for errors and omissions and corrected as necessary prior to data entry. Data was entered in the PLOTS database and checked again for accuracy (QC) with special attention paid to UTMs and classification labels.

Thematic Accuracy Assessment Analysis

Following data entry and QC procedures, accuracy assessment analysis was conducted using both standard accuracy assessment analysis (USGS-NPS 2006) and modified fuzzy set analysis as performed for other NPS vegetation mapping efforts (Hansen et al. 2004; Salas et al. 2005; Cogan et al. 2005).

Accuracy Assessment Statistics: The statistical methods used in this analysis are described in detail in the document Accuracy Assessment Procedures (USGS-NPS 2006). To begin the accuracy assessment, the map classes in the reference data (from the sampled AA plots) were compared to the predicted map classes at the locations on the map. Contingency matrices were generated showing reference map classes in columns, predicted map classes in rows, and the number of points assigned to each in the body of the matrix. The matching pairs show up as values along the diagonal.

The overall accuracy of the map was calculated by dividing the number of matching pairs by the total number of pairs in the matrix. Kappa values were calculated to adjust for the chance occurrence of matching pairs. Two forms of accuracy were then computed for each individual map class: user's accuracy and producer's accuracy.

User's accuracy describes the probability of actually finding, for example, a Broadleaf Cattail Marsh on the ground where one is marked on the map. It is defined as the number of matches between the map and the reference data for a given class divided by the total number of samples that fell into the map class on the map. The difference between these two numbers is due to errors of omission.

Producer's accuracy describes the probability that, for example, when standing in a Broadleaf Cattail Marsh, the map will agree. It is defined as the number of matches between the map and the reference data for a given class divided by the total number of samples of the class in the reference data. The difference between these two numbers is due to errors of commission.

Fuzzy Set Accuracy Assessment: The program standards are seldom met with a strict binary 'right/wrong' approach. More importantly, binary classification does not capture the shades of variation across landscapes. Communities rarely have discrete boundaries or homogenous representation. Often, a point on the ground can represent multiple map classes to varying degrees, these names being somewhat open to the interpretation of the AA field crews. Also, where communities tend to have transitions zones or ecotones along their boundaries, photo interpreters must draw concise lines. Fuzzy set accuracy assessment takes these and other limitations into account by defining degrees of 'rightness' and allowing points to be seen as correct based on predefined levels of error, as shown in Table 5.

Each AA plot was reviewed and assigned to a fuzzy level of correctness based on its primary and secondary associations, vegetation description, plot photos and position relative to polygon boundaries.

Fuzzy level five, or Binary Accuracy, was equivalent to the binary assessment, and included plots in which the primary association matched the mapped map class.

Fuzzy level four, or Acceptable Accuracy, included plots that met either of the requirements listed in Table 5. An example of a plot with Acceptable Accuracy is AA point number 78. This plot was located in a recent expansion of a Prairie Dog Complex within a Blue Grama - Buffalograss Herbaceous Vegetation polygon. Floristically, it was equal to a Blue Grama - Buffalograss Herbaceous Vegetation, and this label was added as a secondary association during data QA/QC procedures.

Fuzzy level three, or Reasonable Accuracy, included plots that were similar in structural composition and species dominance to the map class, but did not meet any of the strict requirements for fuzzy level four. An example of a plot with Reasonable Accuracy is AA point number 60. This plot was located in a Sand Sagebrush / Sand Bluestem Shrubland polygon, but was called Sand Sagebrush / Blue Grama Shrubland by the field crew. These two map units are similar in structural composition (they are both shrublands) and in species dominance (both contain Sand Sagebrush and similar grass species). Fuzzy levels two and one were not considered to be correct, and were not analyzed.

Contingency matrices were generated for level five (Binary Accuracy), level four (Acceptable Accuracy) and level three (Reasonable Accuracy). Overall accuracy, kappa values, and user's

Table 5. Fuzzy Level Ranking Criteria for AA Plots (Adapted from Hansen et al. 2004).

Fuzzy Level	Description
5	Exact match: The reference data is an exact match to the map class.
4	Acceptable Error: If any of the following criteria were met, the case was considered acceptable error: 1) The reference data are the same as a map class in the nearest adjacent polygon and is within 12m of that polygon (distance chosen based on project specific considerations); or 2) The reference data has an alternative correct reference label that was described in the field, which was correct for the map class.
3	Reasonable error: The map class has similar structural composition and species dominance.
2	Vague Similarity: The map class has a similar formation type, but not similar species composition.
1	Complete error: No similarity in the species or structural composition.

and producer's accuracy with 90% confidence intervals were calculated at each of these levels, weighting the map classes by the proportion of the map that each included. These statistics were computed with the use of Kappa analysis extension for ArcView (Jennes and Wynne, 2006). Classes with only one or two plots were excluded from these statistics. The polygons of these classes were too small and infrequent to be sampled with statistical accuracy. The total area excluded from the AA statistics is 17.5 hectares, and constitutes 1.8% of the study area.

Program Standards: The kappa values, as well as user's and producer's accuracy for each individual map class, are used as the final measures of map accuracy. Vegetation Mapping Program thematic accuracy standards call for 80% accuracy with a 90% confidence interval for overall accuracy and user's and producer's accuracy for each map class. The standard for overall accuracy was considered to have been met when the Kappa value was above 80%. The class accuracies were considered to have been met when 80% fell within the confidence interval.

Element Occurrence Records

Element occurrence records (EOR's) for natural community elements of biodiversity tracked by CNHP (Colorado Natural Heritage Program 2007) were developed from plot data and vegetation mapping at the site. EOR's were written for globally vulnerable or imperiled natural communities using the Heritage Methodology described in the Introduction.

Results

Field Data Collection

A CNHP field crew collected data from 79 sample plots during August and September of 2005 (Figure 7). Of the 79 data points collected, 31 were full vegetation plots and 48 were the shorter observation points. Due to lack of landowner permission to perform field work throughout much of the authorized SAND boundary, all of the vegetation relevé plots were confined to the established SAND boundary. Where permission was granted, observation point data were collected (see Appendix A for field forms). Plots were distributed throughout the established park boundary in all of the community types found there. Data from these plots were reviewed for accuracy and entered into the PLOTS database in the fall of 2005.

Vegetation Classification

The SAND plot dataset had 31 samples and 110 species. Species that only occurred in a single plot were removed from the dataset for the multivariate analyses resulting in 71 species in the analyses. A majority of the removed entities were identified only to genus or were found elsewhere on the property but were not as well-represented within plots. No outliers were identified within the plot dataset. Average total plant cover for all species in all plots was 73.4% with a range of 40.1 to 110.2%. Species richness, or the average number of species per plot, was 12.6 with a range of three to 25 species. Beta diversity is a measure of heterogeneity within the dataset or a measure of variation in species composition within a geographic area (Legendre et al. 2005); it is the ratio of the total number of species to the average number of species. Beta diversity was 5.63 across the analysis SAND dataset, which suggests significant heterogeneity. Simpson's index of diversity (McCune and Grace 2002) is a measure of relative abundance of species within a plot (or the probability of two individuals that are randomly selected from a plot or site are different species); it ranges from zero to one with higher numbers inferring greater species diversity. Simpson's index of diversity was 0.79 across all classification plots with a range of 0.314 to 0.942. A list of plant species encountered during all field work at SAND is found in Appendix D.

Cluster Analysis ISA informed pruning of the resulting cluster dendrogram at six groups with distance measured by objective function (Figure 8). After this point, clusters of one or two plots appear. The resulting dendrogram shows very low chaining at 3.52% with approximately 60% of the information in the original data retained at this level of clustering as measured using objective function. MRPP tests on cluster groups suggested significant differences between groups at this level of clustering ($A=0.089$, $p=0.00023$). The six plant associations derived from the classification are listed in Table 6.

Secondary cluster analysis on subgroups was performed to elucidate vegetation patterns and detail. Analysis of just the Plains cottonwood plots revealed a gradient of vegetation abundance upstream to downstream. There was more western wheatgrass in the understory upstream. Progressing downstream, alkali sacaton became more abundant in the middle reach followed by switchgrass increasing in abundance at the downstream end. Analysis of just the sand sagebrush

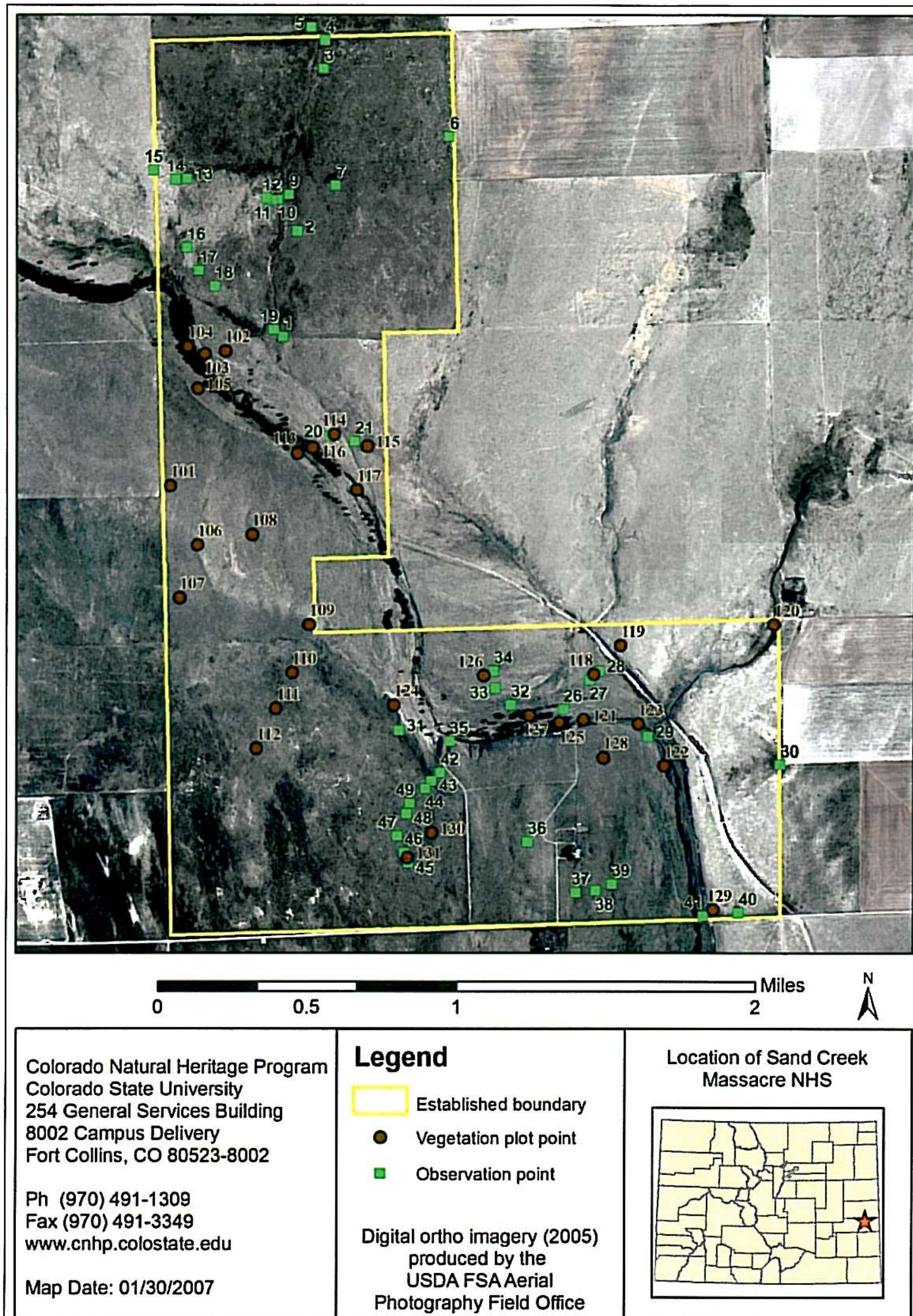

Figure 7. Location of plots and observation points at Sand Creek Massacre National Historic Site.

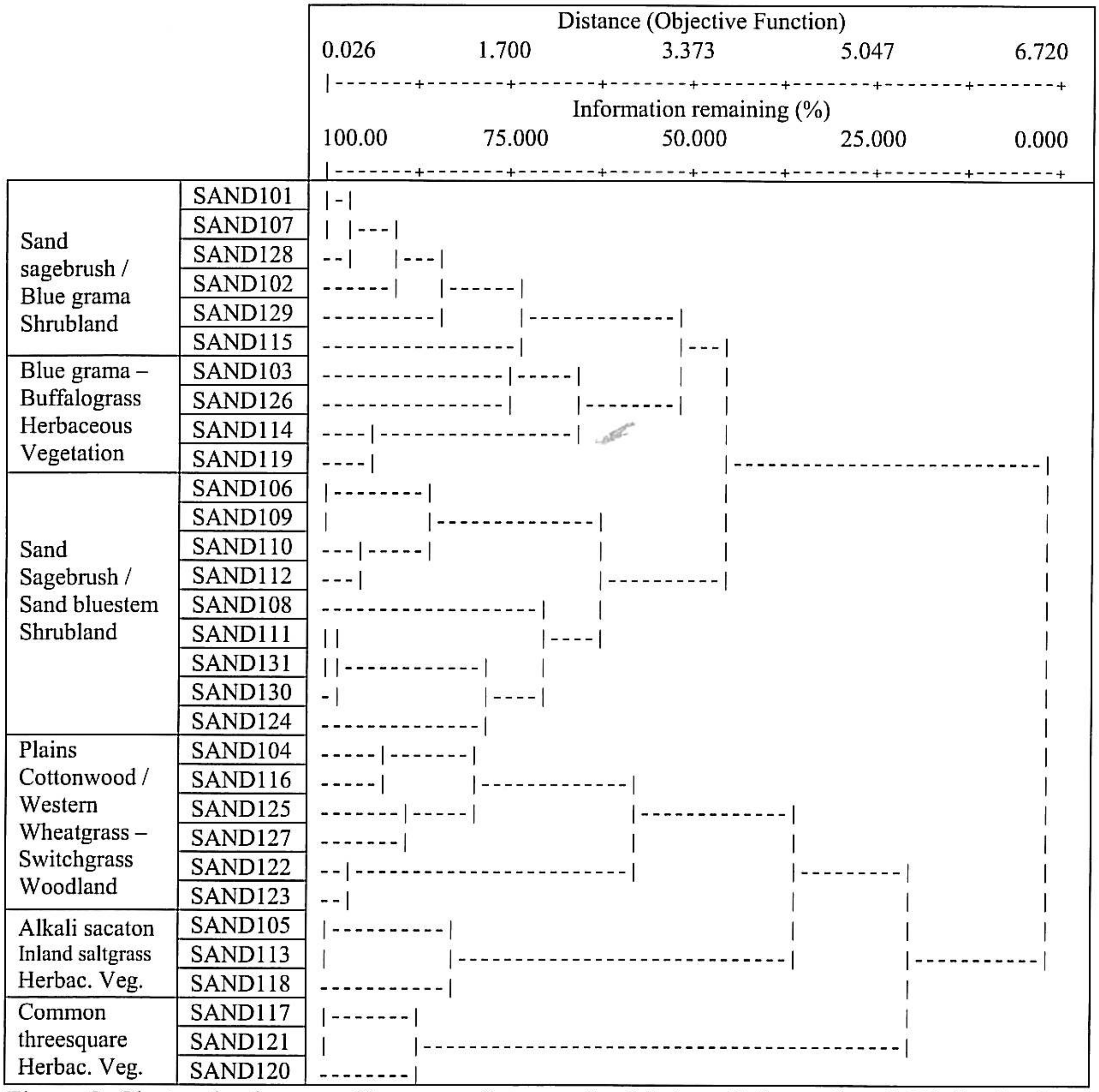

Figure 8. Cluster dendrogram (Sorenson distance, flexible beta linkage, ß = -0.25) for the Sand Creek Massacre National Historic Site dataset showing the attribution of plant association to each plot.

plots did not elucidate strong patterns but resulted in a somewhat definitive split between the shrublands found on the terraces and those on the rolling sandhills in the southwest portion of the property. On the terraces there is greater plant cover and greater litter and blue grama is strongly dominant in the understory, whereas the slopes, knolls, and swales have somewhat greater species diversity and higher proportion of bare soil present.

Divisions in the plot data outlined by TWINSPAN corroborate the primary and secondary cluster analyses and roughly follow landform. The first divisions roughly split out jurisdictional wetlands and also split riparian vegetation on the ancient stream terraces from the surrounding

Table 6. Plant associations identified at Sand Creek Massacre National Historic Site.

Elcode	Global Name	Common Name	G Rank	S Rank	CNHP Tracking Status
CEGL001459	*Artemisia filifolia / Andropogon hallii* Shrubland	Sand Sagebrush / Sand Bluestem Shrubland	G3?	S2	Y
CEGL002176	*Artemisia filifolia / Bouteloua gracilis* Shrubland	Sand Sagebrush / Blue Grama Shrubland	GNR		
CEGL001756	*Bouteloua gracilis - Buchloe dactyloides* Herbaceous Vegetation	Blue Grama - Buffalograss Shortgrass Prairie	G4	S2?	P
CEGL005024	*Populus deltoides / Pascopyrum smithii - Panicum virgatum* Woodland	Plains Cottonwood / Western Wheatgrass – Switchgrass Woodland	GNR	S2	Y
CEGL001587	*Schoenoplectus pungens* Herbaceous Vegetation	Bulrush Wet Meadow	G3G4	S3	Y
CEGL001687	*Sporobolus airoides - Distichlis spicata* Herbaceous Vegetation	Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation	G4?		

uplands. Secondary divisions separate woodland from wet meadows and sand sagebrush shrubland from shortgrass prairie.

NMS revealed that ground cover data elucidated the primary axes in ordination space. A two-dimensional solution was recommended by the analysis with a final stress of 15.4 in 110 iterations. The ordination represented 75.7% of the variation in the dataset, with 56.2% loaded on axis 1 and 9.1% on axis 2 (Figure 9). Bare soil showed a strong relationship with knoll/bluff and bench plots (sand sagebrush plots), whereas litter was high in stream terraces and in the floodplain and channel (plains cottonwood, alkali sacaton-inland saltgrass, and common threesquare plots).

Summary of physiognomic types

A single woodland association was identified at SAND and is represented by six plots with plains cottonwood. These plots comprise 19% of the plots in the dataset. Two shrubland associations were elucidated, both with sand sagebrush. As mentioned above, the shrublands on the ancient terraces differed from those on the undulating uplands south of the creek. The terraces are characterized by Sand Sagebrush / Blue Grama (*Artemisia filifolia / Bouteloua gracilis*) Shrubland, whereas the bluffs, slopes, knolls, and swales express Sand Sagebrush / Sand Bluestem (*Artemisia filifolia / Andropogon hallii*) Shrubland type at SAND. The latter association has greater diversity and abundance of tallgrass species like sand bluestem, sand reed, and sideoats grama in addition to more forb diversity. There were 16 sand sagebrush plots in the dataset, which represented 52% of the plots collected. Three herbaceous associations comprise the remainder of the vegetation at SAND, all graminoid dominated. Two of the herbaceous associations are found within the drainage corridors on the property, including that of the Big Sandy Creek and its tributaries; these are Common Threesquare (*Schoenoplectus pungens*) Herbaceous Vegetation and Alkali Sacaton – Inland Saltgrass (*Sporobolus airoides – Distichlis spicata*) Herbaceous Vegetation. Common Threesquare Herbaceous Vegetation

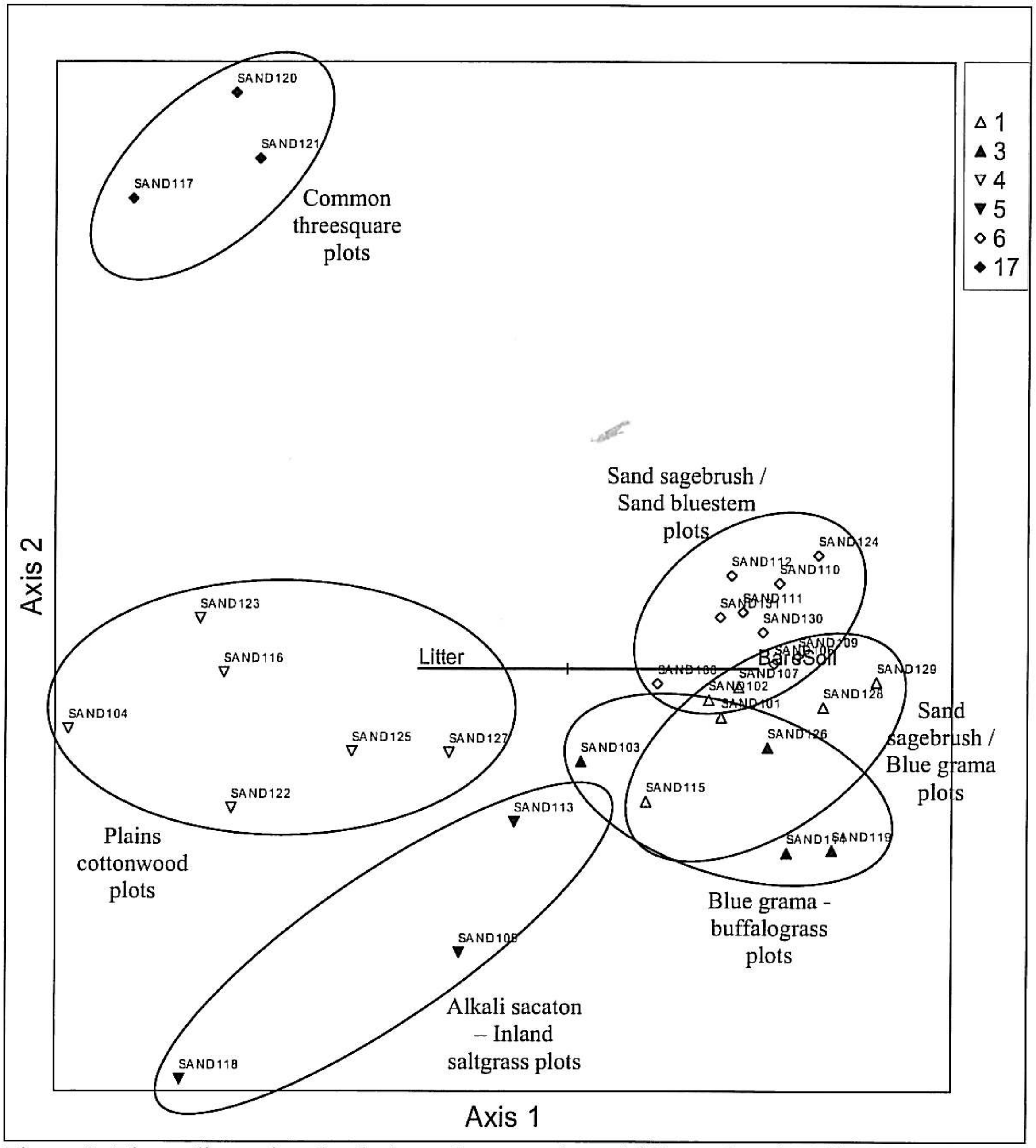

Figure 9. Three-dimensional solution of nonmetric multidimensional scaling (NMS) ordination (random starting configuration, Sorenson distance, forty runs with real data) of Sand Creek Massacre National Historic Site classification dataset.

occupies the damp swales and pools in the active stream channel; these can hold water throughout the growing season and are likely spring-fed. Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation occupies the immediate terraces adjacent to the stream and tributary channels. It has dense vegetative cover and dense thatch. The third graminoid association is Blue Grama – Buffalograss (*Bouteloua gracilis – Buchloe dactyloides*) Herbaceous Vegetation. This association occurs both in the Big Sandy riparian channel on terraces adjacent to the cottonwood gallery as well as on the loamier, less shrubby north- and northeast side of the creek. Away from the riparian channel, this vegetation association is habitat for black-tailed prairie dog colonies and their associated wildlife species, which are expanding on SAND.

Observation point data elucidated other local vegetation phenomena on SAND. The northern section of the established boundary is represented by reclaimed agricultural land and is currently a form of mixedgrass prairie and weedy patches. Likewise, tamarisk (*Tamarix ramosissima*) invasion and subsequent control measures have left a small area of vegetation that differs from the natural riparian vegetation. On the west edge of the established boundary just north of Big Sandy Creek is a dense patch of kochia (*Kochia [=Bassia] scoparia*). The former extent of tamarisk within the established boundary is unknown. Lastly, within the sandhills on the southwest corner of the established boundary are a series of small saline spots within the sand sage shrubland. These areas were all less than the minimum mapping unit but are noticeable on the aerial photography (see Figure 1). These occupy local minima within the swales in this area. These are largely characterized by bare ground with a ring of alkali sacaton and/or inland saltgrass with occasional alkali muhly (*Muhlenbergia asperifolia*).

Photographic database

The classification plot and AA point photos can be found in the geodatabase provided with this report. These are hotlinked to plot locations and viewable by selecting the desired plot using the hotlink tool. As such, they can be easily queried or selected by location. In most cases four photos, one taken in each of the cardinal directions from the plot center, are linked to each point. There are 124 frames associated with the classification plots from 2005, and 507 frames associated with the AA points gathered in 2006.

Vegetation Map

A total of 12,525 acres (5069 ha) comprising the authorized boundary of SAND were mapped (Figure 10). The area mapped within the established Park boundary was 2382 acres (964 ha). Eleven map units were used to describe the landscape (Table 7). Of these, four were non-natural map units (Agriculture, Disturbed, Development, Reclaimed agricultural land). The most frequently occurring map unit within the entire mapping area was Blue Grama – Buffalograss Herbaceous Vegetation, with 20 polygons ranging in size from 0.03 acres (0.01 ha) to 1201 acres (454 ha). The most abundant map unit in terms of area was Sand Sagebrush / Sand Bluestem covering 3759 acres (1521 ha) or about 30% of the project area. Spatial statistics for each of the map units are listed in Table 7. Polygon size ranged from 0.03 acres (0.01 ha) to 3003 acres (1215 ha) with the mean polygon size being 251.4 acres (101.7 ha). Appendix E.

Accuracy Assessment

The accuracy assessment data collection was completed by CNHP between August and September of 2006. Figure 11 shows the distribution of 134 plots collected across the park.

Overall Accuracy

Overall map accuracy was very high at fuzzy level 5 (Binary Accuracy), and was found to reach program standards at level 4 (Acceptable Accuracy), as summarized in Table 8. Contingency tables showing the distribution of errors can be found in Appendix F.

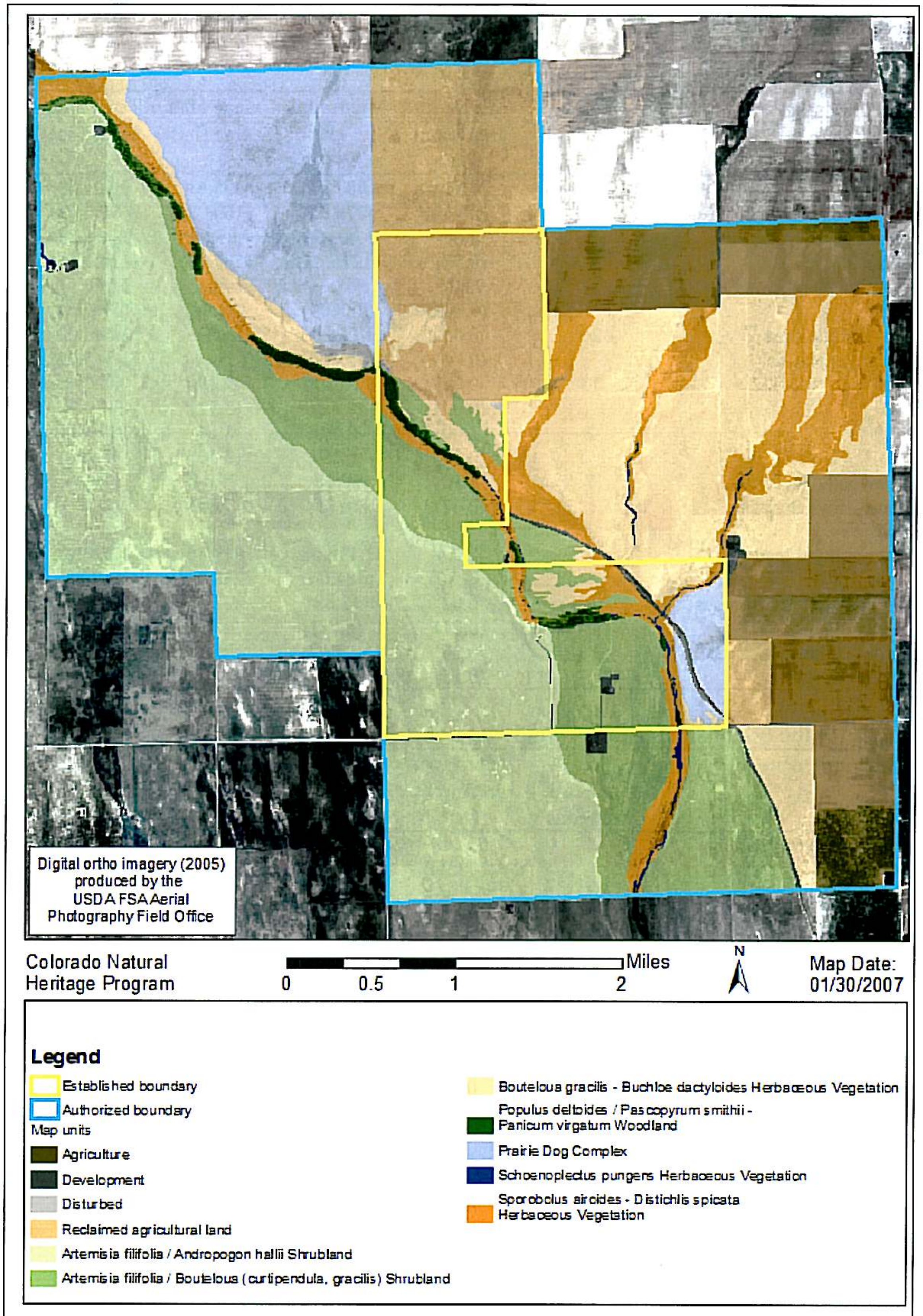

Figure 10. Preliminary vegetation map of Sand Creek Massacre National Historic Site.

Table 7. Area totals for final map classes.

a. Area totals for the authorized SAND boundary.

Map unit name	Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
Agriculture	4	262.92 (106.40)	687.81 (278.35)	395.41 (160.02)	1,581.65 (640.07)
Sand Sagebrush / Sand Bluestem Shrubland	3	2.40 (0.97)	3,003.11 (1215.32)	1,252.95 (507.05)	3,758.85 (1,521.16)
Sand Sagebrush / Blue Grama Shrubland	6	23.26 (9.41)	563.61 (228.09)	196.15 (79.38)	1,176.91 (476.28)
Blue Grama– Buffalograss Herbaceous Vegetation	20	0.03 (0.01)	1,121.01 (453.66)	162.25 (65.66)	3,245.03 (1,313.22)
Development	13	0.22 (0.09)	20.80 (8.42)	9.19 (3.72)	119.48 (48.35)
Disturbed	2	2.00 (0.81)	15.28 (6.19)	8.64 (3.50)	17.29 (7.00)
Plains Cottonwood / Western Wheatgrass – Switchgrass Woodland	7	1.16 (0.47)	60.18 (24.35)	19.41 (7.85)	135.84 (54.97)
Reclaimed agricultural land	2	83.64 (33.85)	1,196.08 (484.04)	639.86 (258.94)	1,279.72 (517.89)
Common Threesquare Herbaceous Vegetation	15	0.02 (0.01)	11.68 (4.73)	2.21 (0.89)	33.12 (13.40)
Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation	15	0.36 (0.15)	397.17 (160.73)	78.40 (31.73)	1,176.06 (475.94)

b. Area totals for the established SAND boundary.

Map unit name	Total number of polygons	Minimum area acres (ha)	Maximum area acres (ha)	Mean area acres (ha)	Total area acres (ha)
Sand Sagebrush / Sand Bluestem Shrubland	1	677.09 (273.94)	677.09 (273.94)	677.09 (273.94)	677.09 (273.94)
Sand Sagebrush / Blue Grama Shrubland	5	23.26 (9.41)	234.73 (94.97)	107.59 (43.53)	537.96 (217.65)
Blue Grama– Buffalograss Herbaceous Vegetation	14	0.02 (0.01)	101.17 (40.93)	24.82 (10.04)	372.23 (150.60)
Development	6	0.01 (0.00)	14.2 (5.74)	4.58 (1.85)	27.48 (11.12)
Disturbed	1	1.99 (0.04)	1.99 (0.81)	1.99 (0.81)	1.99 (0.81)
Plains Cottonwood / Western Wheatgrass – Switchgrass Woodland	6	0.09 (0.47)	30.34 (12.28)	9.23 (3.73)	64.61 (26.14)
Reclaimed agricultural land	1	558.08 (225.79)	558.08 (225.79)	558.08 (225.79)	558.08 (225.79)
Common Threesquare Herbaceous Vegetation	10	0.02 (0.01)	8.96 (3.63)	1.18 (0.48)	12.96 (5.24)
Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation	6	10.55 (4.27)	55.89 (22.61)	26.04 (10.54)	182.31 (73.76)

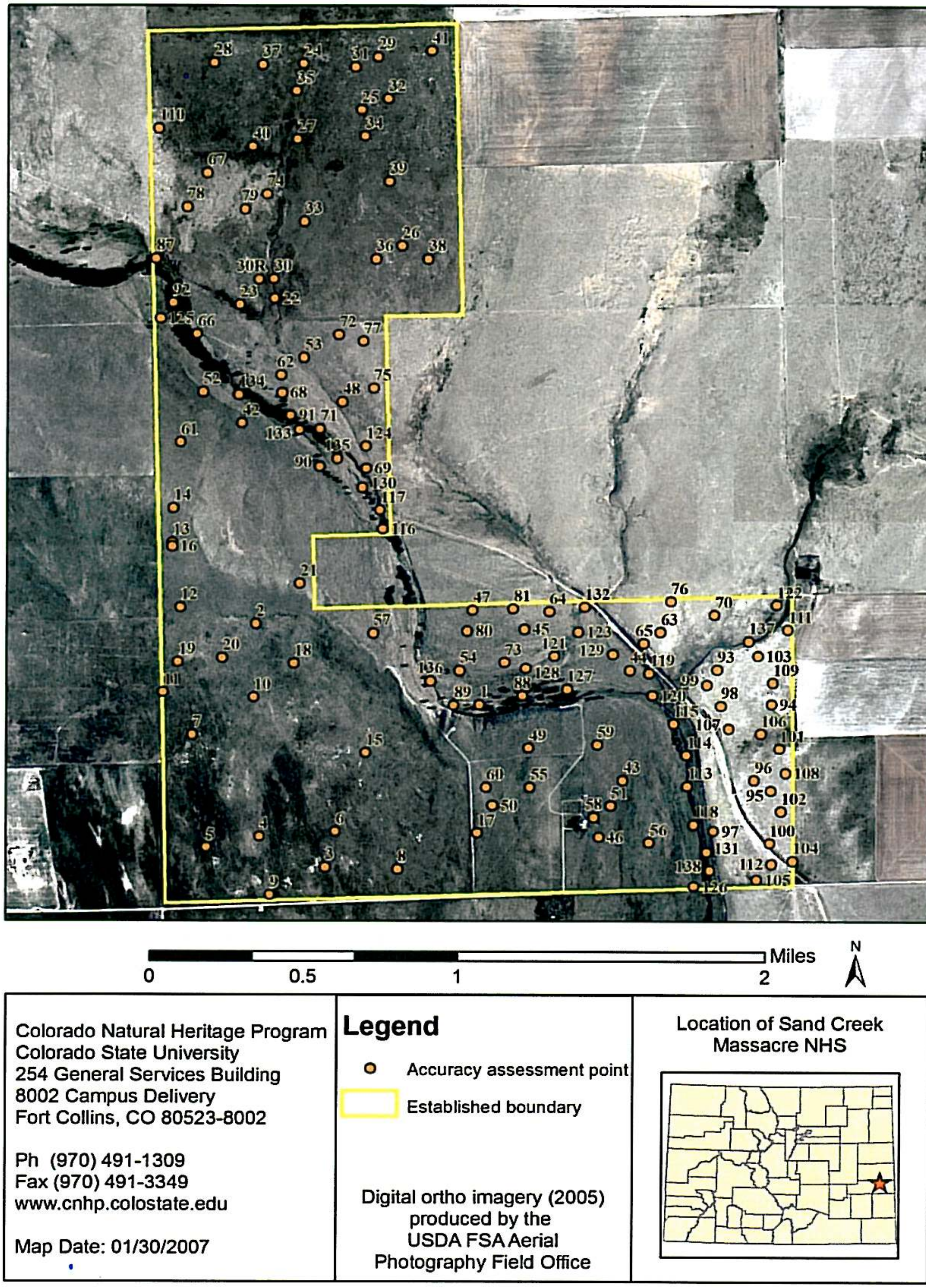

Figure 11. Accuracy assessment (AA) points at Sand Creek Massacre National Historic Site.

Table 8. Weighted overall map accuracy and Kappa values (with 90% Confidence Intervals) for each fuzzy set level

Fuzzy Level	Overall Accuracy	Kappa Value
5 - Binary Accuracy	81% (75% - 86%)	76%
4 - Acceptable Accuracy	85% (80% - 90%)	81%
3 - Reasonable Accuracy	94% (91% - 98%)	93%

Accuracy Assessment by Map Class

1. Sand Sagebrush / Sand Bluestem Shrubland: This map class reached program standards at level 5 and reached 100% user's and producer's accuracy at level 3. The only confusion was with floristically similar map class 2, Sand Sagebrush / Blue Grama Shrubland.

2. Sand Sagebrush / Blue Grama Shrubland: User's accuracy was 90% at level 5, with the only confusion coming from AA plots classified as map class 1, Sand Sagebrush / Sand Bluestem Shrubland. Producer's accuracy reached 81% at level 3. Sources of error were confusion with map classes 1, 3 and 10. Class 3, Blue Grama - Buffalograss Herbaceous Vegetation, is floristically similar to this class, but lacks Sand Sagebrush.

3. Blue Grama - Buffalograss Herbaceous Vegetation: Producer's accuracy for this class was 100% at level 5. User's accuracy was initially low due to errors in mapping Prairie Dog Complexes. Seven plots were taken where the mapped class was Blue Grama - Buffalograss Herbaceous Vegetation, but prairie dogs had expanded their range into the prairie and the field crew keyed the plots to Prairie Dog Complex. Additional error came from confusion with Sand Sagebrush / Blue Grama Shrubland. At level 4, user's accuracy was 68%, with an upper confidence interval of 86%. It reached 84% at level 3.

4. Development: This class was not included in the AA statistics. Two plots were placed in this class, but both were on the line with neighboring polygons, and field crews sampled those other polygons. This class contains mostly roads and buildings that were not difficult to delineate. However, no definitive statement of accuracy can be made about this class.

5. Disturbed: This class was not included in the AA statistics. One of two polygons was sampled and found to be correct at level 5.

6. Plains Cottonwood / Western Wheatgrass - Switchgrass Woodland: At level 5, user's accuracy was 100% and producer's accuracy was 83%. One plot was wrong at this level due to positional error.

7. Black-tailed Prairie Dog Town Grassland Complex: At level 5, user's accuracy was 100% and producer's accuracy was 67% with an upper confidence interval of 81%. Error stemmed from prairie dogs expanding their range into Blue Grama - Buffalograss Herbaceous Vegetation. Producer's accuracy reached 88% at level 4.

8. Reclaimed Agricultural Land: At the level 5, user's accuracy was 86% and producer's accuracy was 100%. Confusion was with Blue Grama - Buffalograss Herbaceous Vegetation.

9. Bulrush Wet Meadow: User's accuracy was 100% at level 5. Producer's accuracy was 30% at this level, but was accurate within the confidence interval at level 4. The errors were due to positional accuracy, and this can probably be attributed to the narrow, linear shape of the polygons.

10. Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation: Producer's accuracy was 92% at level 5. Once positional errors were corrected at level 4, user's accuracy was 85%.

11. Broadleaf Cattail Marsh: This class was not included in the AA statistics. One plot was placed in the larger of two polygons. The field crew found that the vegetation was dominated by bulrushes, with some cattail present. The plot was evaluated as correct at level 3.

Element Occurrence Records

EOR's were written for all natural community elements located at the site; these have been added to the CNHP Biotics database. EOR's were generated for Sand Sagebrush / Sand Bluestem Shrubland, Sand Sagebrush / Blue Grama Shrubland, Blue Grama – Buffalograss Herbaceous Vegetation, Plains Cottonwood / Western Wheatgrass – Switchgrass Woodland, Common Threesquare Herbaceous Vegetation, and for Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation through this project. A plant EOR was also written for showy prairie gentian (*Eustoma exaltatum ssp. russellianum*, Figure 12) found in the riparian corridor of Big Sandy Creek.

Photo by S. Neid.

Figure 12. Photo of showy prairie gentian.

Discussion

Most of the field work occurred within the established boundary of SAND; field work was limited by a lack of uniform landowner permission throughout the additional authorized boundary. Vegetation was mapped in the authorized boundary via aerial photo signature and observation point data taken where CNHP staff was granted permission. Field verification of vegetation patterns is recommended in the future, which will also identify variability within the aerial photo signatures within the park and facilitate future mapping efforts.

Accuracy Assessment: Upon direct comparison of the AA plots to the map polygons, the thematic accuracy was nearly at the acceptable 80% level at Binary Accuracy (Fuzzy Level 5). The majority of the error at this level was due to prairie dog complexes being regarded as a separate map unit from Blue Grama – Buffalograss Herbaceous Vegetation, which is the primary habitat of black-tailed prairie dogs. Expansion of the prairie dog colonies into previously un-colonized areas of shortgrass prairie contributed approximately 50% of the binary error. Another confounding factor of the Binary Accuracy was the similarity and inter-relationships between the two sand sagebrush associations, which generally differ in graminoid composition and landform position. There were areas in the more irregular terrain of the sandhills that lacked tallgrass species characteristic of the Sand Sagebrush / Sand Bluestem Shrubland that is mapped there; this especially occurs in the north end of the sandhills on the established park boundary. Another area with a localized cluster of binary accuracy errors occurred on the terrace on the north side of Big Sandy Creek between the creek and Chivington Ditch. Current vegetation of this terrace is a mosaic of Sand Sagebrush / Blue Grama Shrubland, Blue Grama – Buffalograss Herbaceous Vegetation, and Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation. This area appears to be impacted by the Chivington Ditch; aerial photos show moisture backing up behind the Ditch. Field reconnaissance suggests that the terrace below the Ditch is drying out; sand sagebrush and blue grama appear to be invading swards of alkali sacaton and inland saltgrass. The mosaic of vegetation patches is intricate and likely will continue along a drier trajectory. Another area with clusters of accuracy assessment error occurred in the floodplain where the narrow, braided channel of Big Sandy Creek has a mosaic of thin bands of vegetation (1-3m wide). Due to the spatial character of these polygons, AA points often were nearly always distributed on a map line making AA difficult. The remaining error was largely a result of localized occurrences of weeds (Russian thistle [*Salsola australis*], kochia) that affected plant composition or unmapped areas of sand sagebrush that did not show strong aerial photo signature on screen. With these errors addressed, greater than 80% accuracy was achieved at Fuzzy Level 4 and greater than 90% accuracy achieved at Fuzzy Level 3.

Vegetation Map: Following a second field season at SAND, map units were revisited and modified to more accurately identify vegetation patterns at the site. After the first field season, prairie dog complex was identified as a map unit based on precedence set earlier in the season by other mapping projects in the region (Stevens et al. In press). Little vegetation data was collected within the prairie dog colonies for classification purposes due to safety concerns for staff and to avoid disturbing wildlife (prairie dogs, burrowing owls). Although prairie dogs influence plant composition, especially over time, it was deemed that the effects of the colonies on the vegetation at SAND remain within the natural range of variation for Blue Grama – Buffalograss Herbaceous Vegetation and prairie dog complexes were subsumed into that map class to produce a final vegetation map (Figure 13). With the removal of prairie dog complex as a map unit, additional vegetation texture was revealed within the authorized boundary to the west and northwest of the northern end of the established boundary; area of Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation was identified in the drainage bisecting the large prairie dog town.

Future Application of the Vegetation Map: The vegetation map produced for this project provides baseline data for resource management decisions. However, it only reflects a snapshot in time. Plant communities are dynamic entities that can change over time given changes in environmental parameters. For example, plains cottonwood requires flood scouring for regeneration (Mahoney and Rood 1998). Big Sandy Creek has not seen surface flooding of the magnitude required for establishment since the 1950's and 1960's (Labbe and Fausch 2000). With continued lack of flooding and continued drought, the current cottonwood gallery may deteriorate, which will change the character of the riparian corridor. Likewise, drought and grazing management may influence the percent cover of sand sagebrush (McWilliams 2003). Monitoring these changes over time will facilitate adaptive management of park resources.

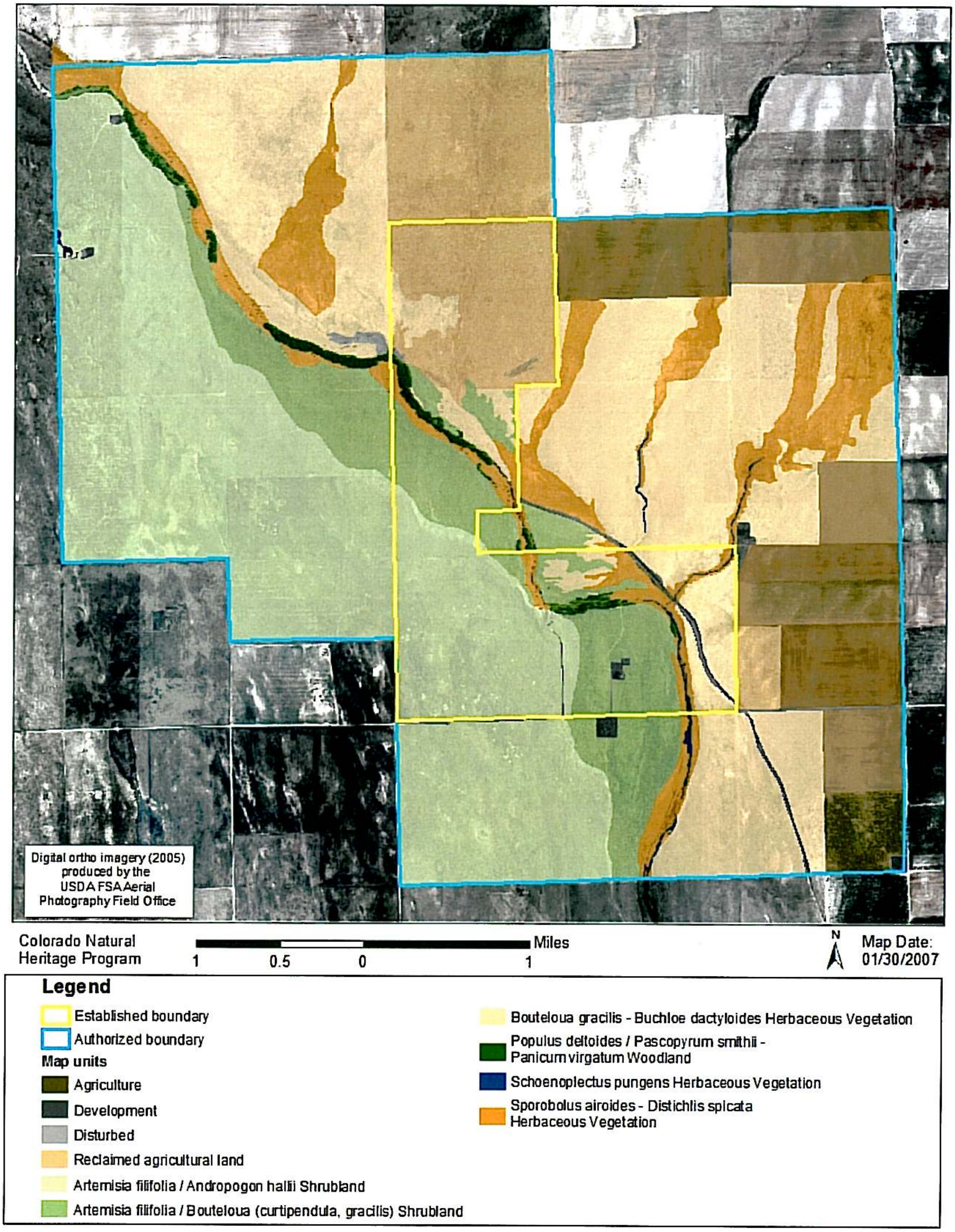

Figure 13. Final vegetation map of Sand Creek Massacre National Historic Site.

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Appendix A. Field form instructions and vegetation plot form.

Vegetation Plot form instructions

Instructions for filling out Fields in the VEGETATION SURVEY FORM

Plot Code
Code indicating the specific plot within the vegetation polygon. For Bents Old Fort, the codes will be "BEOL.VMP..###". Each crew will be assigned a range of plot numbers. Begin with BEOL.VMP.001 and increment up from there. Opportunistic and Random plots will use slightly different systems. Be certain you are not using the same range as another team or numbers you have already used. If someone switches to another team, it is important they know what plot numbers the team will use to identify the data they gather. Before you leave for the field, be sure you know what number range the crew will use and that these are not being used by another team!

Survey Date
Date the survey was taken; month, day, year

Surveyors
Record the three initials of the surveyors present.

Provisional Map Unit
Using the preliminary classification you were provided for the Park, assign the name of the vegetation type that most closely resembles the type you are surveying.

Provisional Association Name
Enter the finest level of the classification possible. If in fact, *none* of the names may be a good fit; you may have found a new type, although this should be the exception and not the rule. If you have a new type, create a provisional name with the dominant and diagnostic species. You must make sure to appropriately mark the field log that you have chosen a new association and not one that was previously on the list given. The 'provisional community name' that is assigned will be used to update the tally of plots needed for each vegetation type.

UTM X
Use GPS if at all possible. If you can't get a GPS reading, estimate coordinates from a topo map and note on the form that this method was used.

UTM Y
Use GPS if at all possible. If you can't get a GPS reading, estimate coordinates from a topo map and note on the form that this method was used.

GPS Accuracy
Note the error in the GPS reading off your unit (PDOP).

Location comments
Enter a simple monument to help someone find the plot again. Put comments on the plot marker here, for instance if you had to place the plot marker in a corner instead of the center of the plot. Record here if you moved a DPL to be more representative.

Plot Length and Plot Width
Enter diameter for circular plots and width and length dimensions for square or rectangular plots. Choose the appropriate plot size based on the following:

Vegetation Class	Standard Plot Dimensions	PLOT AREA
Forest	11.3 m radius or 20 m x 20 m	**400 m^2**
Woodland	11.3 m radius or 20 m x 20 m	**400 m^2**
Shrubland	11.3 m radius or 20 m x 20 m	**400 m^2**
Dwarf-shrubland	5.65 m radius or 10 m x 10 m	**100 m^2**
Herbaceous	5.65 m radius or 10 m x 10 m	**100 m^2**
Nonvascular	2.82 m radius or 5 m x 5 m	**25 m^2**

Camera and Photographs
We are taking digital pictures of the plots on "flashcard" memory cards. Note the flashcard number and frame numbers of each photo. Be sure to have taken a photo of the GPS screen everyday or at least every other day.

Plot Representativeness
Does this plot represent the full variability of the polygon/stand? If not, were additional plots taken? Note additional species not seen in the plot in the space provided below. Note: we distinguish in this section the plot's ability to represent the stand or polygon you are sampling as one component and the ability of this sample to represent the range of variability of the association in the entire mapping area. The former comment may be ascertained by reconnaissance of the stand. The latter comment comes only after some familiarity with the vegetation type throughout the mapping area and may be left blank if you have no opinion at this time.

ENVIRONMENTAL DESCRIPTION

Elevation
Elevation of the plot. Specify whether in feet of meters (this will depend on the units used on the GPS or on the topographic map being used). In general, we have determined that the reading you get from a topo map, provided you are certain where you are, is more accurate than the average reading from the GPS unit. Thus, please attempt to estimate your elevation with the topo map.

Slope
Measure the slope in **degrees** using a clinometer at the plot, not the general slope.

Aspect
Measure the slope aspect using a compass (be sure to correct for the magnetic declination). Note: all compasses should be pre-set to an average declination for the park and thus, readings from the compasses carried by the field crews may be directly noted.

Topographic Position
Topographic position of the plot. <u>Choose one</u>:

INTERFLUVE (crest, summit, ridge). Linear top of ridge, hill, or mountain; the elevated area between two fluves (drainageways) that sheds water to the drainageways.

HIGH SLOPE (shoulder slope, upper slope, convex creep slope). Geomorphic component that forms the uppermost inclined surface at the top of a slope. Includes the transition zone from backslope to summit. Surface is dominantly convex in profile and erosional in origin.

HIGHLEVEL (mesa). Level top of a plateau.

MIDSLOPE (transportational midslope, middle slope). Intermediate slope position.

BACKSLOPE (dipslope). Subset of midslopes that are steep, linear, and may include cliff segments (fall faces).

STEP IN SLOPE (ledge, terracette). Nearly level shelf interrupting a steep slope, rock wall, or cliff face.

LOWSLOPE (lower slope, foot slope, colluvial footslope). Inner gently inclined surface at the base of a slope. Surface profile is generally concave and a transition between midslope or backslope, and toeslope.

TOESLOPE (alluvial toeslope). Outermost gently inclined surface at base of a slope. In profile, commonly gentle and linear and characterized by alluvial deposition.

LOW LEVEL (terrace). Valley floor or shoreline representing the former position of an alluvial plain, lake, or shore.

CHANNEL WALL (bank). Sloping side of a channel.

CHANNEL BED (narrow valley bottom, gully, arroyo, wash). Bed of single or braided watercourse commonly barren of vegetation and formed of modern alluvium.

BASIN FLOOR (depression). Nearly level to gently sloping, bottom surface of a basin.

Landform

Choose one (the best representative if more than one type) landform that describes the site where the plot was taken. Note on the code sheet the landform choices are listed at different scales. Thus, one can select more than one for plot if appropriate (e.g., mountain could be macro and ridge could be meso scale). You can add to the list for Bents Old Fort and Sand Creek areas. Just be consistent so we can analyze by landform so be simple and not wordy.

LANDFORM (from Glacier)	Levee
Alluvial fan	Meander belt
Bench	Meander scar
Bottomland	Moraine (undifferentiated)
Canyon	Mound
Channel	Mountain valley
Cirque floor	Mountain (s)
Cliff	Mountain-valley fan
Colluvial slope	Mud flat
Dome	Patterned ground (undifferentiated)
Drainage channel	Periglacial boulderfield
Draw	Pinnacle
Earth flow	Plateau

Eroded bench Eroding stream channel system, Erosional stream terrace Escarpment Flood plain Fluvial Glaciated uplands Gorge Ground moraine Hanging valley Hills Hillslope bedrock outcrop Island Knob Knoll Lake/pond Lake bed Lake plain Lake terrace Lateral moraine Lava flow (undifferentiated) Ledge	Ravine Ridge Ridge and valley Ridgetop bedrock outcrop Rim Riverbed Rock fall avalanche Saddle Scour Seep Upper 1/3 of slope Middle 1/3 of slope Lower 1.3 of slope Slump pond Soil creep slope Stream terrace (undifferentiated) Streambed Swale Talus Tarn Toe slope Valley floor

Surficial Geology

Note the geologic substrate influencing the plant community (bedrock or surficial materials). Accurately recording the geology at the plot is especially important if the plot is on an inclusion in the type on the geology map. Choose the best one that describes the plot, try to only choose one if possible.

SURFICIAL GEOLOGY descriptive terms

IGNEOUS ROCKS
Granite *Light*
Diorite *50/50*
Gabbro *Dark*

SEDIMENTARY ROCKS
Conglomerate
Breccia
Sandstone
Siltstone

METAMORPHIC ROCKS
Gneiss

GLACIAL DEPOSITS
Lacustrine (lake) and fluvial (river) deposits (glacio-fluvial, fluvio-lacustrine, freshwater sandy beaches, stony/gravelly shoreline)

ORGANIC DEPOSITS
Peat (with clear fibric structure)
Muck
Marsh, regularly flooded by lake or river (high mineral content)

SLOPE AND MODIFIED DEPOSITS
Colluvial (deposition by mass movement (direct gravitational action) and local, unconcentrated runoff (overland flow)
Alluvial (deposition by concentrated running water)
Aeolean (wind deposition)
Solifluction, landslide

Cowardin System / Hydrology

If the system is a wetland, check off the name of the USFWS system which best describes its hydrology and landform. Choose one: Upland, Palustrine, Riverine, or Lacustrine. Indicate "upland" if the system is not a wetland.

Next, assess the hydrologic regime of the plot using the descriptions below (adapted from Cowardin et al. 1979).

PERMANENTLY FLOODED - Water covers the land surface at all times of the year in all years. Equivalent to Cowardin's "permanently flooded."

SEASONALLY FLOODED - Surface water is present for extended periods during the growing season, but is absent by the end of the growing season in most years. The water table after flooding ceases is very variable, extending from saturated to a water table well below the ground surface. Includes Cowardin's Seasonal, Seasonal-Saturated, and Seasonal-Well Drained modifiers.

SEMIPERMANENTLY FLOODED - Surface water persists throughout growing season in most years except during periods of drought. Land surface is normally saturated when water level drops below soil surface. Includes Cowardin's Intermittently Exposed and Semipermanently Flooded modifiers.

TEMPORARILY FLOODED - Surface water present for brief periods during growing season, but water table usually lies well below soil surface. Often characterizes flood-plain wetlands. Equivalent to Cowardin's Temporary modifier.

INTERMITTENTLY FLOODED - Substrate is usually exposed, but surface water can be present for variable periods without detectable seasonal periodicity. Inundation is not predictable to a given season and is dependent upon highly localized rain storms. This modifier was developed for use in the arid West for water regimes of Playa lakes, intermittent streams, and dry washes but can be used in other parts of the U.S. where appropriate. This modifier can be applied to both wetland and non-wetland situations. Equivalent to Cowardin's Intermittently Flooded modifier.

SATURATED - Surface water is seldom present, but substrate is saturated to surface for extended periods during the growing season. Equivalent to Cowardin's Saturated modifier.

UNKNOWN - The water regime of the area is not known. The unit is simply described as a non-tidal wetland.

Environmental Comments
Enter any additional noteworthy comments on the environmental setting. This field can be used to describe site history such as fire events (date since last fire or evidence of severity) as well as other disturbance or reproduction factors including animal disturbance.

Ground Cover
Estimate ground cover to the nearest percentage by each category, excluding plant basal area. Total should sum to 100%.

Soil Texture
Using the following key, assess average soil texture. In addition to this key you can choose Peat, Muck or Loam.

Simplified Key to Soil Texture (Brewer and McCann 1982)

A1 Soil does not remain in a ball when squeezed..sand

A2 Soil remains in a ball when squeezed..B

B1 Squeeze the ball between your thumb and forefinger, attempting to make a ribbon that you push up over your finger.
Soil makes no ribbon..loamy sand

B2 Soil makes a ribbon; may be very short..C

C1 Ribbon extends less than 1 inch before breaking...D

C2 Ribbon extends 1 inch or more before breaking..E

D1 Add excess water to small amount of soil
Soil feels at least slightly gritty..loam or sandy loam

D2 Soil feels smooth...silt loam

E1 Soil makes a ribbon that breaks when 1 2 inches long;
cracks if bent into a ring..F

E2 Soil makes a ribbon 2+ inches long; does not crack when bent into a ring..................G

F1 Add excess water to small amount of soil;
soil feels at least slightly gritty.......................................sandy clay loam or clay loam

F2 Soil feels smooth..silty clay loam or silt

G1 Add excess water to a small amount of soil;
soil feels at least slightly gritty..sandy clay or clay

G2 Soil feels smooth...silty clay

Soil Drainage

The soil drainage classes are defined in terms of (1) actual moisture content (in excess of field moisture capacity) and (2) the extent of the period during which excess water is present in the plant-root zone. It is recognized that permeability, level of groundwater, and seepage are factors affecting moisture status. However, because these are not easily observed or measured in the field, they cannot generally be used as criteria of moisture status. It is further recognized that soil profile morphology, for example mottling, normally, but not always, reflects soil moisture status. Although soil morphology may be a valuable field indication of moisture status, it should not be the overriding criterion. Soil drainage classes cannot be based solely on the presence or absence of mottling. Topographic position and vegetation as well as soil morphology are useful field criteria for assessing soil moisture status.

RAPIDLY DRAINED - The soil moisture content seldom exceeds field capacity in any horizon except immediately after water addition. Soils are free from any evidence of gleying throughout the profile. Rapidly drained soils are commonly coarse textured or soils on steep slopes.

WELL DRAINED - The soil moisture content does not normally exceed field capacity in any horizon (except possibly the C) for a significant part of the year. Soils are usually free from mottling in the upper 3 feet, but may be mottled below this depth. B horizons, if present, are reddish, brownish, or yellowish.

MODERATELY WELL DRAINED - The soil moisture in excess of field capacity remains for a small but significant period of the year. Soils are commonly mottled (chroma < 2) in the lower B and C horizons or below a depth of 2 feet. The Ae horizon, if present, may be faintly mottled in fine-textured soils and in medium-textured soils that have a slowly permeable layer below the solum. In grassland soils the B and C horizons may be only faintly mottled and the A horizon may be relatively thick and dark.

SOMEWHAT POORLY DRAINED - The soil moisture in excess of field capacity remains in subsurface horizons for moderately long periods during the year. Soils are commonly mottled in the B and C horizons; the Ae horizon, if present, may be mottled. The matrix generally has a lower chroma than in the well-drained soil on similar parent material.

POORLY DRAINED - The soil moisture in excess of field capacity remains in all horizons for a large part of the year. The soils are usually very strongly gleyed. Except in high-chroma parent materials the B, if present, and upper C horizons usually have matrix colors of low chroma. Faint mottling may occur throughout.

VERY POORLY DRAINED - Free water remains at or within 12 inches of the surface most of the year. The soils are usually very strongly gleyed. Subsurface horizons usually are of low chroma and yellowish to bluish hues. Mottling may be present but at the depth in the profile. Very poorly drained soils usually have a mucky or peaty surface horizon.

VEGETATION DESCRIPTION

Leaf Phenology
Select one value which best describes the leaf phenology of the dominant stratum. The dominant stratum is the uppermost stratum that contains at least 10% cover.

EVERGREEN - Greater than 75% of the total woody cover is never without green foliage.

COLD DECIDUOUS – More than 75% of the total woody cover sheds its foliage in connection with an unfavorable season mainly characterized by winter frost.

MIXED EVERGREEN - COLD DECIDUOUS - Evergreen and deciduous species generally contribute 25-75% of the total woody cover. Evergreen and cold-deciduous species admixed.

PERENNIAL - Herbaceous vegetation composed of more than 50% perennial species.

ANNUAL - Herbaceous vegetation composed of more than 50% annual species.

Leaf Type
Select one value which best describes the leaf form of the dominant stratum. The dominant stratum is the uppermost stratum that contains at least 10% cover.

BROAD-LEAVED - Woody vegetation primarily broad-leaved (generally contributes greater than 50 percent of the total woody cover).

NEEDLE-LEAVED - Woody vegetation primarily needle-leaved (generally contributes greater than 50 percent cover).

MICROPHYLLOUS - Woody cover primarily microphyllous.

GRAMINOID - Herbaceous vegetation composed of more than 50 percent graminoid/stipe leaf species.

FORB (BROAD-LEAF-HERBACEOUS) - Herbaceous vegetation composed of more than 50% broad-leaf forb species.

PTERIDOPHYTE - Herbaceous vegetation composed of more than 50 percent species with frond or frond-like leaves.

Physiognomic Class
Choose one:

Forest:	Trees with their crowns overlapping (generally forming 60-100% cover).
Woodland:	Open stands of trees with crowns not usually touching (generally forming 25-60% cover). Canopy tree cover may be less than 25% in cases where it exceeds shrub, dwarf-shrub, herb, and nonvascular cover, respectively.

Shrubland:	Shrubs generally greater than 0.5 m tall with individuals or clumps overlapping to not touching (generally forming more than 25% cover, trees generally less than 25% cover). Shrub cover may be less than 25% where it exceeds tree, dwarf-shrub, herb, and nonvascular cover, respectively. Vegetation dominated by woody vines is generally treated in this class.
Dwarf-Shrubland:	Low-growing shrubs usually under 0.5 m tall. Individuals or clumps overlapping to not touching (generally forming more than 25% cover, trees and tall shrubs generally less than 25% cover). Dwarf-shrub cover may be less than 25% where it exceeds tree, shrub, herb, and nonvascular cover, respectively
Herbaceous:	Herbs (graminoids, forbs, and ferns) dominant (generally forming at least 25% cover; trees, shrubs, and dwarf-shrubs generally with less than 25% cover). Herb cover may be less than 25% where it exceeds tree, shrub, dwarf-shrub, and nonvascular cover, respectively.
Nonvascular:	Nonvascular cover (bryophytes, non-crustose lichens, and algae) dominant (generally forming at least 25% cover). Nonvascular cover may be less than 25% where it exceeds tree, shrub, dwarf-shrub, and herb cover, respectively.
Sparse Vegetation:	Abiotic substrate features dominant. Vegetation is scattered to nearly absent and generally restricted to areas of concentrated resources (total vegetation cover is typically less than 10% and greater than 0%).

Strata/Lifeform, Height, Cover, Diagnostic Species
Visually divide the community into vegetation layers (strata). Indicate the average height class of the stratum in the first column, using the Height Scale on the form. Enter the average percent cover class of the whole stratum in the second column, using the Cover Scale on the form. Many plots will have only a few of the possible layers. Height and Cover classes are also listed below. Then list a few of the most common species in each stratum.

Trees are defined as single- or few-stemmed woody plants, generally greater than 5 m in height and 10 cm DBH at maturity and under optimal growing conditions. Individuals can be determined relatively easily. Shrubs are defined as multiple-stemmed woody plants generally less than 5 m in height at maturity and under optimal growing conditions, and determining individuals can sometimes be difficult.

Herbaceous layers are Ht = total, H1 = Graminoids (grass, sedge, rush), H2 = Forbs (non-graminoid flowering herbaceous), H3 = Ferns and Fern allies, and H4 = tree seedlings. List the dominant species in each stratum. If species known to be diagnostic of a particular vegetation type are present, list these as well, marking them with an asterisk.]

Cover Scale for Strata		Height Scale for Strata	
T	0-1%	01	<0.5 m
P	>1-5%	02	0.5-1m
1 +/-	>5-15%	03	1-2 m
2	>15-25%	04	2-5 m
3	>25-35%	05	5-10 m
4	>35-45%	06	10-15 m
5	>45-55%	07	15-20 m
6	>55-65%	08	20-35 m
7	>65-75%	09	35 - 50 m
8	>75-85%	10	>50 m
9	>85-95%		
10	>95-		

Vegetation Comments
Record comments on the vegetation. If there is damage to certain spcies etc. Record any thoughts about the make up of the stratums. This is a good place to add any other basic comments as well.

Species/ Percent Cover Table
Starting with the uppermost stratum, list all the species present (record the latin name and not a code) and cover class (using the 12 point scale) and percent cover of each species in that particular stratum. Indicate strata in the left-hand columns. If in the tree layer (single-stemmed woody plants, generally 5 m in height or greater at maturity), note in the "T" column if T1 (emergent tree), T2 (tree canopy), or T3 (tree sub-canopy). If in the shrub layer, note in the "S" column if S1 (tall shrub, > 2m), S2 (short shrub, < 2m), or S3 (dwarf shrub. < 0.5m). If in the ground layer, note in the "G" column if H1 (herbaceous - graminoid), H2 (Herbaceous Forb), H3 (Herbaceous Fern), H4 (Tree Seedlings), N (nonvascular other than ferns), V (vine/liana), or E (epiphyte).

Make sure to double check with the dominant strata list and make sure all species that you said were part of the dominant strata are present in the species list.

*For plots with trees, estimate cover of seedlings, saplings, mature (all others), and total cover for **each** tree species. Use a separate line for each and assign the most appropriate strata class (by height). Seedlings are generally less than 1.5 m, but that may vary by species.

BEOL / SAND Code List - Cheatsheet

LANDFORM

- Alluvial fan
- Bench
- Bottomland
- Canyon
- Channel
- Cirque floor
- Cliff
- Colluvial slope
- Dome
- Drainage channel
- Draw
- Earth flow
- Eroded bench
- Eroding stream channel system
- Erosional stream terrace
- Escarpment
- Flood plain
- Fluvial
- Glaciated uplands
- Gorge
- Ground moraine
- Hanging valley
- Hills
- Hillslope bedrock outcrop
- Island
- Knob
- Knoll
- Lake/pond
- Lake bed
- Lake plain
- Lake terrace
- Lateral moraine
- Lava flow (undifferentiated)
- Ledge
- Levee
- Meander belt
- Meander scar
- Moraine (undifferentiated)
- Mound
- Mountain valley
- Mountain (s)
- Mountain-valley fan
- Mud flat
- Patterned ground (undifferentiated)
- Periglacial boulderfield
- Pinnacle
- Plateau
- Ravine
- Ridge
- Ridge and valley
- Ridgetop bedrock outcrop
- Rim
- Riverbed
- Rock fall avalanche
- Saddle
- Scour
- Seep
- Upper 1/3 of slope
- Middle 1/3 of slope
- Lower 1.3 of slope
- Slump pond
- Soil creep slope
- Stream terrace (undifferentiated)
- Streambed
- Swale
- Talus
- Tarn
- Toe slope
- Valley floor

ASPECT

Flat (n/a)	
Variable	
N	338-22
NE	23-67
E	68-112
SE	113-157
S	158-202
SW	203-247
W	248-292
NW	293-337

SOIL TEXTURE

- sand
- loamy sand
- sandy loam
- silt loam
- sandy clay loam
- clay loam
- silty clay loam
- silt
- sandy clay
- clay
- silty clay
- peat
- muck
- loam

DRAINAGE

- Rapidly drained
- Well drained
- Moderately well drained
- Somewhat poorly drained
- Poorly drained
- Very poorly drained

TOPOGRAPHIC POSITION

- Interfluve
- High Slope
- Highlevel
- Midslope
- Backslope
- Step In Slope
- Lowslope
- Toeslope
- Low Level
- Channel Wall
- Channel Bed
- Basin Floor

SURFICIAL GEOLOGY

descriptive terms

IGNEOUS ROCKS

- Granite *Light*
- Diorite *50/50*
- Gabbro *Dark*

SEDIMENTARY ROCKS

- Conglomerate
- Breccia
- Sandstone
- Siltstone

METAMORPHIC ROCKS

- Gneiss

GLACIAL DEPOSITS

- Lacustrine (lake) and fluvial (river) deposits (glacio-fluvial, fluvio-lacustrine, freshwater sandy beaches, stony/gravelly shoreline)

ORGANIC DEPOSITS

- Peat (with clear fibric structure)
- Muck
- Marsh, regularly flooded by lake or river (high mineral content)

SLOPE AND MODIFIED DEPOSITS

- Colluvial (deposition by mass movement (direct gravitational action) and local, unconcentrated runoff (overland flow)
- Alluvial (deposition by concentrated running water)
- Aeolean (wind deposition)
- Solifluction, landslide

NPS VEGETATION MAPPING PROGRAM: BENTS OLD FORT AND SAND CREEK

IDENTIFIERS/LOCATORS

Plot Code: BEOL.VMP.__________ ☐ Observation Plot Survey Date: _____/_____/ 2005 Surveyors: ______________________
SAND.VMP.__________

Provisional Map Unit Name: ____

Provisional Association Name: ____

UTM Zone: 13 UTM X: __ __ __ __ __ __ (m E) UTM Y: __ __ __ __ __ __ __ (m N) Accuracy __________m

Location Comments:

Plot length(m):______ Plot width(m):______

Azimuth: ________° Radius(m):________

Camera #: ____________ CF Card #: ____________

Photo #: N__________ E__________ S__________ W__________

Plot representativeness (discuss decisions for placement and/or reasons for non-representativeness)

a. Representativeness of association (if known):

b. Representativeness of plot in stand:

ENVIRONMENTAL DESCRIPTION

Elevation ______________m Slope ______________° Aspect______________°

Topographic Position (see cheat sheet)______________ Landform (see cheat sheet)______________

Surficial Geology (see cheat sheet)______________________________

Cowardan System:	Soil Texture:	Soil Drainage:	% Ground Cover: *(Sum = 100%)*
___ Upland	___ sand	___ Rapidly drained	___ Litter / duff
___ Palustrine	___ loamy sand	___ Well drained	___ Wood (> 1 cm)
___ Riverine	___ sandy loam	___ Moderately well drained	___ Bare soil
___ Lacustrine	___ silt loam	___ Somewhat poorly drained	___ Sand (0.1-2 mm)
	___ sandy clay loam	___ Poorly drained	___ Small rocks (0.2-10 cm)
Hydrology:	___ clay loam	___ Very poorly drained	___ Large rocks (> 10 cm)
___Permanently Flooded	___ silty clay loam		___ Bedrock
___Seasonally Flooded	___ silt		___ Water
___Semi-permanently Flooded	___ sandy clay		___ Moss
___Temporarily Flooded	___ clay		___ Lichen
___Intermittently Flooded	___ silty clay		___ Cryptogam
___Saturated	___ peat		___ Basal area
___Unknown	___ muck		___ Other: ____________
	loam		

Environmental Comments (dynamic stage, fire history, insect damage, animal use evidence, natural or anthropogenic disturbance):

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Height Scale for Strata	Cover Scale for Strata
Trees and Shrubs __Evergreen __Cold-deciduous __Mixed evergreen-cold-deciduous Herbs ___Annual ___Perennial	___Broad-leaved ___Needle-leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte	___Forest ___Woodland ___Shrubland ___Dwarf Shrubland ___Herbaceous ___Nonvascular ___Sparsely Vegetated	01 <0.5 m 02 0.5-1m 03 1-2 m 04 2-5 m 05 5-10 m 06 10-15 m 07 15-20 m 08 20-35 m 09 35 – 50 m 10 >50 m	T 0-1% P >1-5% 1 >5-15% +/- 2 >15-25% 3 >25-35% 4 >35-45% 5 >45-55% 6 >55-65% 7 >65-75% 8 >75-85% 9 >85-95% 10 > 95%

	Height Class	Cover Class	Dominant Species (mark Diagnostics with *)
T1 Emergent	______	______	______________________________
T2 Canopy	______	______	______________________________
T3 Sub-canopy	______	______	______________________________
S1 Tall shrub	______	______	______________________________
S2 Short Shrub	______	______	______________________________
S3 Dwarf-shrub	______	______	______________________________
Ht Herbaceous	______	______	______________________________
H1 Graminoids	______	______	______________________________
H2 Forbs	______	______	______________________________
H3 Ferns	______	______	______________________________
H4 Seedlings	______	______	______________________________
N Non-vascular	______	______	______________________________
V Vine/liana	______	______	______________________________
E Epiphyte	______	______	______________________________

Vegetation Comments:

PlotCode BEOL.VMP. SAND.VMP.

Species/percent cover: Starting with the uppermost stratum, list all species with % cover for each species in the stratum. For each tree species estimate seedling, sapling, mature, and total cover indicating stratum . <u>Also list any additional species outside the plot at the end of the table or designate with a 0 in Cover Class column.</u>

Cover Scale for Strata			
T	0-1%	5	>45-55%
P	>1-5%	6	>55-65%
1	>5-15% +/-	7	>65-75%
2	>15-25%	8	>75-85%
3	>25-35%	9	>85-95%
4	>35-45%	10	> 95%

Stratum	Species Name	Cover Class	Stratum	Species Name	Cover Class
Stratum	Species Name	Cover Class	Stratum	Species Name	Cover Class
				Species outside plot:	

Appendix B. Accuracy Assessment (AA) plot form.

NPS VEGETATION MAPPING PROGRAM: BENTS OLD FORT AND SAND CREEK ACCURACY ASSESSMENT SURVEY FORM

IDENTIFIERS/LOCATORS

Plot Code: BEOL.VMP. AA___________ Survey Date: ____/____/ 2006 Surveyors: ______________________
SAND.VMP. AA___________.

Provisional Map Unit Name: ____

Provisional Association Name:

UTM Zone: 13 UTM X: __ __ __ __ __ __ __ (m E) UTM Y: __ __ __ __ __ __ __ (m N) Accuracy __________m

Location Comments:

Photo #: N___________ E___________ S___________ W___________

Plot representativeness (discuss decisions for placement and/or reasons for non-representativeness)

c. Representativeness of association (if known):

d. Representativeness of plot in stand:

ENVIRONMENTAL DESCRIPTION

Elevation _______________m Slope _________________° Aspect_____________________°

Topographic Position (see cheat sheet)_______________________ Landform (see cheat sheet)_______________________

Surficial Geology (see cheat sheet)____

Cowardan System:	Soil Texture:	Soil Drainage:	% Ground Cover: *(Sum = 100%)*
___ Upland	___ sand	___ Rapidly drained	___ Litter / duff
___ Palustrine	___ loamy sand	___ Well drained	___ Wood (> 1 cm)
___ Riverine	___ sandy loam	___ Moderately well drained	___ Bare soil
___ Lacustrine	___ silt loam	___ Somewhat poorly drained	___ Sand (0.1-2 mm)
	___ sandy clay loam	___ Poorly drained	___ Small rocks (0.2-10 cm)
Hydrology:	___ clay loam	___ Very poorly drained	___ Large rocks (> 10 cm)
___Permanently Flooded	___ silty clay loam		___ Bedrock
___Seasonally Flooded	___ silt		___ Water
___Semi-permanently Flooded	___ sandy clay		___ Moss
___Temporarily Flooded	___ clay		___ Lichen
___Intermittently Flooded	___ silty clay		___ Cryptogam
___Saturated	___ peat		___ Basal area
___Unknown	___ muck		___ Other: ____________
	___ loam		

Environmental Comments (dynamic stage, fire history, insect damage, animal use evidence, natural or anthropogenic disturbance):

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Height Scale for Strata	Cover Scale for Strata
Trees and Shrubs __Evergreen __Cold-deciduous __Mixed evergreen-cold-deciduous Herbs ___Annual ___Perennial	___Broad-leaved ___Needle-leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte	___Forest ___Woodland ___Shrubland ___Dwarf Shrubland ___Herbaceous ___Nonvascular ___Sparsely Vegetated	01 <0.5 m 02 0.5-1m 03 1-2 m 04 2-5 m 05 5-10 m 06 10-15 m 07 15-20 m 08 20-35 m 09 35 – 50 m 10 >50 m	T 0-1% P >1-5% 1 >5-15% +/- 2 >15-25% 3 >25-35% 4 >35-45% 5 >45-55% 6 >55-65% 7 >65-75% 8 >75-85% 9 >85-95% 10 > 95%

	Height Class	Cover Class	Dominant Species (mark Diagnostics with *)
T1 Emergent	______	______	______________________________
T2 Canopy	______	______	______________________________
T3 Sub-canopy	______	______	______________________________
S1 Tall shrub	______	______	______________________________
S2 Short Shrub	______	______	______________________________
S3 Dwarf-shrub	______	______	______________________________
Ht Herbaceous	______	______	______________________________
H1 Graminoids	______	______	______________________________
H2 Forbs	______	______	______________________________
H3 Ferns	______	______	______________________________
H4 Seedlings	______	______	______________________________
N Non-vascular	______	______	______________________________
V Vine/liana	______	______	______________________________
E Epiphyte	______	______	______________________________

Vegetation Comments:

Appendix C. Key to Natural Vegetation Types at Sand Creek Massacre National Historic Site and local vegetation descriptions.

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Key to Natural Vegetation Types at Sand Creek Massacre National Historic Site
February 2007

1. Upland vegetation 2
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2. Plowed agricultural fields .... **Agriculture**
2. Not a plowed field... 3

3. Abundance of weedy species like *Kochia scoparia* and/or evidence of *Tamarix ramosissima* removal .... **Disturbed**
3. Not as above.. 4

4. Old homestead or roads .... **Development**
4. Not as above.. 5

5. *Artemisia filifolia* not present or not abundant (<10%) 6
5. *Artemisia filifolia* present AND abundant (>10% cover) 7

6. Grassland with abundant *Bouteloua curtipendula, Bouteloua gracilis, Sporobolus cryptandrus*, and little or no *Buchloe dactyloides* (if present, only at low cover, <1%)....................................
....**Reclaimed Agricultural Land**
6. Grassland dominated by *Bouteloua gracilis. Buchloe dactyloides* may be codominant. No or very little *Boutloua curtipendula*...
.... ***Bouteloua gracilis – Buchloe dactyloides*** **Herbaceous Vegetation**

7. *Artemisia filifolia* shrubland with tallgrass species like *Calamovilfa longifolia, Bouteloua curtipendula*, or *Andropogon hallii* present (usually in low abundance, <1-5%) ....
.... ***Artemisia filifolia / Andropogon hallii*** **Shrubland**
7. *Artemisia filifolia* shrubland with *Bouteloua gracilis* as the dominant graminoid, generally on terraces above the riparian channel............... ***Artemisia filifolia / Bouteloua gracilis*** **Shrubland**

8. *Populus deltoides* canopy present...
.................................***Populus deltoides / Pascopyrum smithii – Panicum virgatum*** **Woodland**
8. *Populus deltoides* canopy absent 9

9. Wet areas or swales dominated by *Schoenoplectus pungens. Typha angustifolia* and/or *Schoenoplectus acutus* may also be present....***Schoenoplectus pungens*** **Herbaceous Vegetation**
9. Lacks *Schoenoplectus pungens*.. 10

10. Grassland dominated by *Distichlis spicata, Sporobolus airoides, Panicum obtusum,* and/or *Panicum virgatum*..................***Sporobolus airoides – Distichlis spicata*** **Herbaceous Vegetation**
10. Grassland dominated by short grasses like *Bouteloua gracilis* and/or *Buchloe dactyloides*
.... ***Bouteloua gracilis – Buchloe dactyloides*** **Herbaceous Vegetation**

PLANT ASSOCIATIONS

CEGL001459—*Artemisia filifolia / Andropogon hallii* Shrubland
Sand Sagebrush / Sand Bluestem Shrubland

ENVIRONMENTAL DESCRIPTION

This shrubland occurs on the undulating sand hills above the stream terrace on the south side of Big Sandy Creek. The topography in this area of the property is a result of eolian deposition with sandy knolls and intervening swales. Soils are well-drained to rapidly drained loamy sands and sandy loams with inclusions of mildly saline pockets of sandy clay loam in some swales. Bare ground generally predominates with greater than 50% exposed in most places, often up to 60-70%. Some litter is generally present although the percentage varies.

VEGETATION DESCRIPTION

This sand sage shrubland is characterized by *Artemisia filifolia*. The shrubs are generally robust, growing to 0.5 to 1 meter tall and with an average cover of 25% (ranging from 5-35%). *Yucca glauca* is a common subshrub in many areas, especially knolls and bluffs. The understory is characterized by diverse graminoids and forbs. Graminoids are generally dominant and include *Andropogon hallii, Bouteloua curtipendula, Calamovilfa longifolia, Aristida divaricata,* and *Aristida purpurea* as well as *Bouteloua gracilis*, which is ubiquitously present. The tallgrass species are characteristic of this association. Forbs are often diverse with *Ambrosia psilostachya, Psoralidium tenuiflorum, Psoralidium lanceolatum, Erigeron bellidiastrum, Liatris punctata, Dalea cylindriceps, Machaeranthera pinnatifida, Mentzelia nuda, Helianthus petiolaris, Eriogonum annuum, Conyza canadensis,* and occasionally *Ratibida tagetes, Mirabilis glabra, Oxytropis sericea, Sphaeralcea coccinea,* and *Chamaesyce missurica.* Swales tend to have greater cover of *Eriogonum annuum, Aristida divaricata*, and *Conyza canadensis* whereas knolls and bluffs have greater forb diversity, and more *Yucca glauca, Bouteloua curtipendula, Calamovilfa longifolia,* and *Andropogon hallii.* Small inclusions of bare, saline soil occur in the southern portion of the property; these areas are surrounded by a narrow ring of *Sporobolus airoides* and *Distichlis spicata.*

MOST ABUNDANT SPECIES

Stratum	Species
SHRUB	*Artemisia filifolia*
HERBACEOUS	*Bouteloua curtipendula, Bouteloua gracilis*

CHARACTERISTIC SPECIES

Stratum	Species
SHRUB	*Artemisia filifolia*
HERBACEOUS	*Andropogon hallii, Bouteloua curtipendula, Calamovilfa longifolia*

CLASSIFICATION COMMENTS

This association is similar to *Artemisia filifolia / Bouteloua, gracilis* Shrubland (CEGL002176) at Sand Creek National Historic Site. It may represent a late successional state or less impact from grazing with livestock preferentially consuming tallgrass species. Alternatively, *Artemisia filifolia* may be invading *Bouteloua gracilis* grasslands as a result of grazing management (NRCS 2004).

ELEMENT DISTRIBUTION

This shrubland occurs on the bluffs and undulating sand hills behind them on the south side of Big Sandy Creek above the stream terraces.

ELEMENT SOURCES

Sand Creek National Historic Site Inventory Notes: SAND: 106, 107, 108, 109, 110, 111, 112, 124, 130, 131
Authors: S. Neid
REFERENCES: NRCS (Natural Resources Conservation Service). 2004. Ecological Site Description: Sands (MRLA 67B). Technical Guide Section IIE. Accessible at: http://efotg.nrcs.usda.gov/treemenuFS. aspx?Fips=08043&MenuName=menuCO.zip.

CEGL002176—*Artemisia filifolia / Bouteloua gracilis* Shrubland

Sand Sagebrush / Blue Grama Shrubland

ENVIRONMENTAL DESCRIPTION

This shrubland occurs on flat terraces and benches immediately adjacent to and above the riparian channel of Big Sandy Creek as well as in limited areas on the level bench above the Chivington Ditch east of the creek. The shrubland occurs at toeslopes and low level areas on the property. Soils are well drained sandy loams (with occasional silt loam and sandy clay loam areas closer to the riparian channel). Litter is prevalent in these areas, generally with greater than 50% cover and cryptogamic soil development is common.

VEGETATION DESCRIPTION

This sand sagebrush shrubland is characterized by *Artemisia filifolia*. The shrubs are generally robust, growing to 0.5 to 1 meter tall and with an average cover of 30% (ranging from 10-45%). The herbaceous layer is strongly dominated by *Bouteloua gracilis*, which ranges from 25-55% cover. *Sporobolus cryptandrus* is a common associate and *Hesperostipa comata* is occasionally present. Forbs are less diverse than in the sand hills but include *Machaeranthera pinnatifida, Evolvulus nuttallianus, Cirsium ochrocentrum, Liatris punctata, Conyza canadensis,* and *Sphaeralcea coccinea*. Occasionally *Sporobolus airoides* and *Distichlis spicata* occur, especially where this association grades into *Sporobolus airoides – Distichlis spicata* Herbaceous Vegetation in the riparian corridor.

MOST ABUNDANT SPECIES

Stratum	Species
SHRUB	*Artemisia filifolia*
HERBACEOUS	*Bouteloua gracilis*

CHARACTERISTIC SPECIES

Stratum	Species
SHRUB	*Artemisia filifolia*
HERBACEOUS	*Bouteloua gracilis*

CLASSIFICATION COMMENTS

These plots are fairly species-poor relative to sand sage systems. This association is similar to both *Artemisia filifolia / Andropogon hallii* Shrubland (CEGL001459) and *Bouteloua gracilis – Buchloe dactyloides* Herbaceous Vegetation (CEGL001756) at Sand Creek National Historic Site. It may represent an earlier successional state or more impact from grazing with livestock preferentially consuming tallgrass species. Alternatively, *Artemisia filifolia* may be invading *Bouteloua gracilis* grasslands as a result of grazing management (NRCS 2004).

ELEMENT DISTRIBUTION

This shrubland occurs on flat terraces and benches immediately adjacent to and above the riparian channel of Big Sandy Creek as well as in limited areas on the level bench above the Chivington Ditch east of the creek.

ELEMENT SOURCES

Sand Creek National Historic Site Inventory Notes: SAND: 101, 102, 115, 128, 129

Authors: S. Neid

REFERENCES: NRCS (Natural Resources Conservation Service). 2004. Ecological Site Description: Sands (MRLA 67B). Technical Guide Section IIE. Accessible at: http://efotg.nrcs.usda.gov/treemenuFS.aspx?Fips=08043&MenuName=menuCO.zip.

CEGL001756—*Bouteloua gracilis – Buchloe dactyloides* Herbaceous Vegetation
Blue Grama – Buffalograss Herbaceous Vegetation

ENVIRONMENTAL DESCRIPTION

Shortgrass prairie occurs on the loamier north side of Big Sandy Creek. Best expressions occur on flat, ancient, alluvial terraces adjacent to the riparian corridor and on gently undulating uplands north and east of the riparian corridor. Soils are well-drained and generally loamy with variable areas of sandy loam, silt loam, and silty or sandy clay loam. On the ancient, alluvial terraces, there are more alkaline indicators. Litter is generally high, ranging from 50-95% cover. Cryptogamic soil development is common.

VEGETATION DESCRIPTION

This shortgrass prairie association is characterized by *Buchloe dactyloides* and sod-forming *Bouteloua gracilis*. Occasional graminoid associates include *Sporobolus cryptandrus, Monroa squarrosa, Muhlenbergia torreyi*, and/or *Muhlenbergia arenicola.* Forbs are common but have sparse cover; they include *Callirhoe involucrata, Sphaeralcea coccinea, Oxytropis sericea, Psoralidium tenuiflorum, Mirabilis glabra, Opuntia polyacantha,* and *Machaeranthera pinnatifida.* The expression of this association on the lower terraces within the riparian corridor is more alkaline with *Ratibida tagetes, Iva annua*, and variable amounts of *Sporobolus airoides* and *Distichlis spicata.*

MOST ABUNDANT SPECIES

Stratum	Species
HERBACEOUS	*Buchloe dactyloides, Bouteloua gracilis*

CHARACTERISTIC SPECIES

Stratum	Species
HERBACEOUS	*Buchloe dactyloides, Bouteloua gracilis*

CLASSIFICATION COMMENTS

There are two expressions of this association at Sand Creek National Historic Site; the grassland on the alluvial terraces is elementally different than the expression on the uplands above the bluff on the north and east side of Big Sandy Creek. The shortgrass prairie on the terraces represents the more alkaline end of the range of variability with *Ratibida tagetes, Iva annua, Distichlis spicata*, and occasionally *Sporobolus airoides*, whereas in the uplands farther from the riparian corridor, those species are lacking and a different suite of forbs is present. More plot data is needed to further define this possible distinction.

ELEMENT DISTRIBUTION

Shortgrass prairie occurs on the loamier north side of the Big Sandy and a more alkaline version occupies limited areas on the low terraces immediately adjacent to the stream channel.

ELEMENT SOURCES

Sand Creek National Historic Site Inventory Notes: SAND: 103, 114, 119, 126
Authors: S. Neid

CEGL005024—*Populus deltoides / Pascopyrum smithii – Panicum virgatum* Woodland
Cottonwood / Western Wheatgrass - Switchgrass Woodland

ENVIRONMENTAL DESCRIPTION

The cottonwood woodland occurs along the modern riparian channel and immediately adjacent alluvial terrace. The channel is subtly braided with microtopography created by natural sand or gravel levees intercalated with swales of variable depth. Surface soils are generally clay loams and silty clay loams with pockets of loamy sand and sandy loam. There is significant downed wood (some of which has been cleared and piled outside of the riparian channel for fuel reduction projects). Litter is high, generally greater than 70%. Bare soil occurs in sporadic patches within the braided channel mosaic and is comprised of gravels and sand. Old flood debris is present; the last time the channel had flowing water was reportedly in 1999.

VEGETATION DESCRIPTION

This cottonwood woodland is characterized by *Populus deltoides*, which generally forms even-aged stands in disconnected patches along the length of Big Sandy Creek. Additionally there are several older and larger individuals or small groups of *Populus deltoides* near the older alluvial terraces. Canopy cover averages around 25-35% cover and ranges from 10-65%. Canopy dieback is evident in several areas. The herbaceous layer is dominated by grasses, especially *Pascopyrum smithii* and *Panicum virgatum*. *Pascopyrum smithii* occupies areas with denser canopy and *Panicum virgatum* is more abundant in partial shade to more open situations; *Pascopyrum smithii* is more abundant in upstream areas and *Panicum virgatum* becomes more prevalent in downstream areas where the cottonwood canopy is more sporadic. Common associates include *Elymus canadensis, Buchloe dactyloides*, and *Sporobolus airoides. Distichlis spicata, Muhlenbergia asperifolia*, and *Spartina pectinata* occur infrequently. Forbs are common and can be locally abundant. Species include *Ambrosia psilostachya, Asclepias subverticillata, Ratibida columnifera, Rayjacksonia phyllocephala*, and *Symphyotrichum falcatum* var. *falcatum*. *Tamarix ramosissima* saplings are rare but present.

MOST ABUNDANT SPECIES

Stratum	Species
TREE CANOPY	*Populus deltoides*
HERBACEOUS	*Panicum virgatum, Pascopyrum smithii*

CHARACTERISTIC SPECIES

Stratum	Species
TREE CANOPY	*Populus deltoides*
HERBACEOUS	*Panicum virgatum, Pascopyrum smithii*

OTHER NOTEWORTHY SPECIES

Stratum	Species
SHRUB	*Tamarix ramosissima*

CLASSIFICATION COMMENTS

The character and concept of the cottonwood woodland is similar to the expression at Lake Meredith National Recreation Area (Bell 2005). It has a less diverse and abundant tallgrass component than *Populus deltoides / Panicum virgatum - Schizachyrium scoparium* Woodland (CEGL001454) (see Carsey et al. 2003). Elucidating the relationship of species composition and grazing management in these cottonwood woodlands may illustrate the state of the woodland at this site.

ELEMENT DISTRIBUTION

This cottonwood woodland occurs along the channel of Big Sandy Creek.

ELEMENT SOURCES

Sand Creek National Historic Site Inventory Notes: SAND: 104, 116, 122, 123, 125, 127
Authors: S. Neid **REFERENCES:**

- Bell, J.R. 2005. Descriptions of the Vegetation Associations of Lake Meredith NRA and Alibates Flint Quarries NM. Unpublished report submitted to NatureServe.
- Carsey, K., Kittel, G., Decker, K., Cooper, D.J., and Culver, D. 2003. Field Guide to the Wetland and Riparian Plant Associations of Colorado. Colorado Natural Heritage Program, Colorado State University, Ft. Collins, CO.

CEGL001587—*Schoenoplectus pungens* Herbaceous Vegetation
Common Threesquare Herbaceous Vegetation

ENVIRONMENTAL DESCRIPTION
This emergent wetland association occurs in the channel of Big Sandy Creek on the Sand Creek National Historic Site. Generally this wetland association occurs as small, isolated ephemeral ponds. However, there is greater ponding upstream from where County Road W crosses the creek; the emergent wetland is more extensive and there is surface water throughout the growing season. Soils are poorly drained to very poorly drained muck with pockets of sandy clay. Litter is very high, generally greater than 95%, and composed of last years bulrush stalks. Surface water is absent later in the growing season in many small ponds and channels toward the upstream end of the riparian channel, but persists where the hydrology has been altered by roads and the Chivington Ditch.

VEGETATION DESCRIPTION
This emergent wetland is characterized by *Schoenoplectus pungens*, which is generally dominant and exhibits 65-80% cover. Common associated species include *Muhlenbergia asperifolia*. Where the wetlands have greater surface water, *Schoenoplectus acutus* and/or *Typha angustifolia* are present. Additional species that occur incidentally and sporadically within the wetlands include *Juncus balticus, Iva xanthifolia,* and *Eleocharis palustris*. In several areas *Populus deltoides* regeneration is occurring.

MOST ABUNDANT SPECIES

Stratum	Species
HERBACEOUS	*Schoenoplectus pungens*

CHARACTERISTIC SPECIES

Stratum	Species
HERBACEOUS	*Schoenoplectus pungens*

OTHER NOTEWORTHY SPECIES

Stratum	Species
SHRUB	*Tamarix ramosissima*

CLASSIFICATION COMMENTS
The ponding due to County Road W may be extensive enough to classify the immediate vicinity around the culvert as a small area of *Typha (latifolia, angustifolia)* Western Herbaceous Vegetation (CEGL002010).

ELEMENT DISTRIBUTION
This emergent wetland occurs within the channel of Big Sandy Creek. In the upstream portions of the channel it occurs as small, isolated, ephemeral ponds and in local areas where the channel is deeper. Downstream, near County Road W, the wetland is more extensive.

ELEMENT SOURCES
Sand Creek National Historic Site Inventory Notes: SAND: 117, 120, 121
Authors: S. Neid

CEGL001687—*Sporobolus airoides – Distichlis spicata* Herbaceous Vegetation

Alkali Sacaton - Saltgrass Herbaceous Vegetation

ENVIRONMENTAL DESCRIPTION

This grassland occurs on the alluvial terrace immediately above the active stream channel. It occurs in wide swaths on the inside bends of the creek where the alluvial bench is more extensive. Soils are silty or sandy clay loams. Litter is abundant (>95%) and comprised of grass thatch from previous years growth. Depth to the water table is a significant driver of this association; where it occurs below the Chivington Ditch

VEGETATION DESCRIPTION

The grassland occupying the alluvial terraces above the active channel of Big Sandy Creek are characterized by *Sporobolus airoides* and *Distichlis spicata.* These two species form a patchy mosaic of monotypic as well as mixed swards. *Panicum obtusum* and *Muhlenbergia asperifolia* are frequent. *Asclepias subverticillata* is frequent and can form dense patches within this grassland. Additional associated species include *Ratibida tagetes, Mirabilis glabra, Ambrosia psilostachya, Callirhoe involucrata, Chenopodium berlandieri, Chenopodium subglabrum, Glycyrrhiza lepidota*, and *Sporobolus cryptandrus.*

MOST ABUNDANT SPECIES

Stratum	Species
HERBACEOUS	*Sporobolus airoides, Distichlis spicata*

CHARACTERISTIC SPECIES

Stratum	Species
HERBACEOUS	*Sporobolus airoides, Distichlis spicata, Muhlenbergia asperifolia, Panicum obtusum*

OTHER NOTEWORTHY SPECIES

Stratum	Species
SHRUB	*Tamarix ramosissima*

CLASSIFICATION COMMENTS

This mixed grassland association comprises a tessellated spatial juxtaposition of the monotypic swards of *Sporobolus airoides* and *Distichlis spicata* in addition to the intervening areas where the species are codominant.

ELEMENT DISTRIBUTION

This grassland occurs on older alluvial terraces within the Big Sandy Creek riparian corridor.

ELEMENT SOURCES

Sand Creek National Historic Site Inventory Notes: SAND: 105, 113, 118
Authors: S. Neid

PARK SPECIAL MAP UNITS

Agriculture

This map unit reflects plowed agricultural fields.

Development

This map unit reflects anthropogenic infrastructure and includes roads (wider than 12m), homesteads and associated infrastructure or plantings, and the Chivington Ditch

Disturbed

This map unit reflects anthropogenic activity outside of development areas. These are areas dominated by non-native weedy species like *Bassia (=Kochia) scoparia* and *Salsola australis*, among others. These areas often occur where *Tamarix ramosissima* reduction and removal efforts occurred and where large machinery used to reduce *Salsola* tumbleweeds was used.

Reclaimed agricultural land

This map unit reflects areas of unknown land use history (although presumably plowed agriculture) that have been replanted to native grass species. Within the established park boundary, this occurs in a majority of the northern section. Species composition is a patchy distribution of native grasses and weedy areas comprised of both native and non-native species. Native grasses predominantly include *Bouteloua gracilis, Bouteloua curtipendula, Sporobolus cryptandrus*, and small patches of *Panicum virgatum*. Forb species occasionally occur, including *Sphaeralcea coccinea, Lygodesmia juncea, Astragalus bisulcatus, Physalis heterophylla, Cirsium ochrocentrum*, or *Conyza canadensis*, among others. Weedy areas tend to have more bare ground and abundant *Bassia (=Kochia) scoparia* or *Salsola australis* with or without *Sporobolus cryptandrus*. Local areas with more fine-textured soils have patches of *Buchloe dactyloides*. Sporadic shrubs occur, including *Ericameria nauseosus* and *Artemisia filifolia*, especially near fencelines or on the periphery of the vegetation type.

Appendix D. Plant list for Sand Creek Massacre National Historic Site. Species observed outside of plots have frequency of zero.

PLANTS Code	Latin Name	Common Name	Family Name	Frequency within plots
AMAC2	*Ambrosia acanthicarpa*	flatspine burr ragweed	Asteraceae	0
AMPS	*Ambrosia psilostachya*	Cuman ragweed	Asteraceae	19
ANHA	*Andropogon hallii*	sand bluestem	Poaceae	5
ARAD	*Aristida adscensionis*	sixweeks threeawn	Poaceae	0
ARDI5	*Aristida divaricata*	poverty threeawn	Poaceae	2
ARPU9	*Aristida purpurea*	purple threeawn	Poaceae	9
ARCA14	*Artemisia carruthii*	Carruth's sagewort	Asteraceae	0
ARFI2	*Artemisia filifolia*	sand sagebrush	Asteraceae	16
ARLU	*Artemisia ludoviciana*	white sagebrush	Asteraceae	7
ASCLE	*Asclepias*	milkweed	Asclepiadaceae	0
ASEN	*Asclepias engelmanniana*	Engelmann's milkweed	Asclepiadaceae	1
ASLA4	*Asclepias latifolia*	broadleaf milkweed	Asclepiadaceae	1
ASPU	*Asclepias pumila*	plains milkweed	Asclepiadaceae	0
ASSP	*Asclepias speciosa*	showy milkweed	Asclepiadaceae	2
ASSU2	*Asclepias subverticillata*	horsetail milkweed	Asclepiadaceae	5
ASTRA	*Astragalus*	milkvetch	Fabaceae	2
ASBI2	*Astragalus bisulcatus*	twogrooved milkvetch	Fabaceae	0
ASGR3	*Astragalus gracilis*	slender milkvetch	Fabaceae	0
ASMO7	*Astragalus mollissimus*	woolly locoweed	Fabaceae	0
ASRA2	*Astragalus racemosus*	cream milkvetch	Fabaceae	1
BASC	*Bassia scoparia*	smotherweed	Chenopodiaceae	5
BOLA2	*Bothriochloa laguroides*	silver beardgrass	Poaceae	0
BOCU	*Bouteloua curtipendula*	sideoats grama	Poaceae	7
BOGR2	*Bouteloua gracilis*	blue grama	Poaceae	24
BREU	*Brickellia eupatorioides*	false boneset	Asteraceae	2
BUDA	*Buchloe dactyloides*	buffalograss	Poaceae	8
CALO	*Calamovilfa longifolia*	prairie sandreed	Poaceae	3
CAIN2	*Callirhoe involucrata*	purple poppymallow	Malvaceae	4
CAREX	*Carex*	sedge	Cyperaceae	1
CAPR5	*Carex praegracilis*	clustered field sedge	Cyperaceae	1
CHER2	*Chaetopappa ericoides*	rose heath	Asteraceae	0
CHAMA15	*Chamaesyce*	sandmat	Euphorbiaceae	3
CHMI8	*Chamaesyce missurica*	prairie sandmat	Euphorbiaceae	1
CHBE4	*Chenopodium berlandieri*	pitseed goosefoot	Chenopodiaceae	1
CHSU2	*Chenopodium subglabrum*	smooth goosefoot	Chenopodiaceae	3
CHVE2	*Chloris verticillata*	tumble windmill grass	Poaceae	0
CIRSI	*Cirsium*	thistle	Asteraceae	3
CICA11	*Cirsium canescens*	prairie thistle	Asteraceae	1
CIOC2	*Cirsium ochrocentrum*	yellowspine thistle	Asteraceae	4
COAR4	*Convolvulus arvensis*	field bindweed	Convolvulaceae	0
COCA5	*Conyza canadensis*	Canadian horseweed	Asteraceae	13

PLANTS Code	Latin Name	Common Name	Family Name	Frequency within plots
CRTE4	*Croton texensis*	Texas croton	Euphorbiaceae	2
CYSC3	*Cyperus schweinitzii*	Schweinitz's flatsedge	Cyperaceae	0
DACY	*Dalea cylindriceps*	Andean prairie clover	Fabaceae	4
DISP	*Distichlis spicata*	inland saltgrass	Poaceae	3
DYPA	*Dyssodia papposa*	fetid marigold	Asteraceae	2
ECVI2	*Echinocereus viridiflorus*	nylon hedgehog cactus	Cactaceae	0
ELPA3	*Eleocharis palustris*	common spikerush	Cyperaceae	1
ELCA4	*Elymus canadensis*	Canada wildrye	Poaceae	6
ELEL5	*Elymus elymoides*	squirreltail	Poaceae	1
ERTR3	*Eragrostis trichodes*	sand lovegrass	Poaceae	0
ERNA10	*Ericameria nauseosa*	rubber rabbitbrush	Asteraceae	0
ERBE2	*Erigeron bellidiastrum*	western daisy fleabane	Asteraceae	6
ERAN4	*Eriogonum annuum*	annual buckwheat	Polygonaceae	12
ERCA14	*Erysimum capitatum*	sanddune wallflower	Brassicaceae	0
EUMA8	*Euphorbia marginata*	snow on the mountain	Euphorbiaceae	2
EUEXR	*Eustoma exaltatum ssp. russellianum*	showy prairie gentian	Gentianaceae	0
EVNU	*Evolvulus nuttallianus*	shaggy dwarf morning-glory	Convolvulaceae	4
GAPI	*Gaillardia pinnatifida*	red dome blanketflower	Asteraceae	0
GACO5	*Gaura coccinea*	scarlet beeblossom	Onagraceae	1
GAMO5	*Gaura mollis*	velvetweed	Onagraceae	3
GLLE3	*Glycyrrhiza lepidota*	American licorice	Fabaceae	0
GRIND	*Grindelia*	gumweed	Asteraceae	1
GRSQ	*Grindelia squarrosa*	curlycup gumweed	Asteraceae	5
GUSA2	*Gutierrezia sarothrae*	broom snakeweed	Asteraceae	1
HEAN3	*Helianthus annuus*	common sunflower	Asteraceae	2
HEPE	*Helianthus petiolaris*	prairie sunflower	Asteraceae	7
HECO5	*Heliotropium convolvulaceum*	phlox heliotrope	Boraginaceae	0
HECO26	*Hesperostipa comata*	needle and thread	Poaceae	3
HEVI4	*Heterotheca villosa*	hairy false goldenaster	Asteraceae	3
HOJU	*Hordeum jubatum*	foxtail barley	Poaceae	0
HYFI	*Hymenopappus filifolius*	fineleaf hymenopappus	Asteraceae	0
IPLE	*Ipomoea leptophylla*	bush morning-glory	Convolvulaceae	2
IPLA2	*Ipomopsis laxiflora*	iron ipomopsis	Polemoniaceae	1
IVXA	*Iva xanthifolia*	giant sumpweed	Asteraceae	1
JUBA	*Juncus balticus*	Baltic rush	Juncaceae	1
LACTU	*Lactuca*	lettuce	Asteraceae	1
LASE	*Lactuca serriola*	prickly lettuce	Asteraceae	1
LIPU	*Liatris punctata*	dotted blazing star	Asteraceae	4
LIPU4	*Linum puberulum*	plains flax	Linaceae	1
LITHO3	*Lithospermum*	stoneseed	Boraginaceae	2
LUPU	*Lupinus pusillus*	rusty lupine	Fabaceae	0
LYJU	*Lygodesmia juncea*	rush skeletonplant	Asteraceae	1
MACA2	*Machaeranthera canescens*	hoary tansyaster	Asteraceae	1
MAPI	*Machaeranthera pinnatifida*	lacy tansyaster	Asteraceae	14

PLANTS Code	Latin Name	Common Name	Family Name	Frequency within plots
MATA2	*Machaeranthera tanacetifolia*	tanseyleaf tansyaster	Asteraceae	1
MESA	*Medicago sativa*	alfalfa	Fabaceae	0
MEOF	*Melilotus officinalis*	yellow sweetclover	Fabaceae	1
MENUN	*Mentzelia nuda var. nuda*	bractless blazingstar	Loasaceae	9
MIGL3	*Mirabilis glabra*	smooth four o'clock	Nyctaginaceae	9
MILI3	*Mirabilis linearis*	narrowleaf four o'clock	Nyctaginaceae	1
MINY	*Mirabilis nyctaginea*	heartleaf four o'clock	Nyctaginaceae	3
MOSQ	*Monroa squarrosa*	false buffalograss	Poaceae	2
MUAR2	*Muhlenbergia arenicola*	sand muhly	Poaceae	0
MUAS	*Muhlenbergia asperifolia*	scratchgrass	Poaceae	4
MUTO2	*Muhlenbergia torreyi*	ring muhly	Poaceae	2
OECO2	*Oenothera coronopifolia*	crownleaf evening-primrose	Onagraceae	0
OELA2	*Oenothera latifolia*	mountain evening-primrose	Onagraceae	1
OPUNT	*Opuntia*	pricklypear	Cactaceae	2
OPPO	*Opuntia polyacantha*	plains pricklypear	Cactaceae	3
ORLU	*Orobanche ludoviciana*	Louisiana broomrape	Orobanchaceae	0
ORAS	*Oryzopsis asperifolia*	roughleaf ricegrass	Poaceae	0
OXSE	*Oxytropis sericea*	white locoweed	Fabaceae	5
PAPL12	*Packera plattensis*	prairie groundsel	Asteraceae	1
PASP	*Palafoxia sphacelata*	othake	Asteraceae	0
PACA6	*Panicum capillare*	witchgrass	Poaceae	1
PAOB	*Panicum obtusum*	vine mesquite	Poaceae	0
PAVI2	*Panicum virgatum*	switchgrass	Poaceae	6
PASM	*Pascopyrum smithii*	western wheatgrass	Poaceae	6
PASPA2	*Paspalum*	crowngrass	Poaceae	0
PEHY4	*Pediomelum hypogaeum*	subterranean Indian breadroot	Fabaceae	0
PHCU3	*Phyla cuneifolia*	wedgeleaf	Verbenaceae	2
PHHEF	*Physalis hederifolia var. fendleri*	Fendler's groundcherry	Solanaceae	1
PHHI8	*Physalis hispida*	prairie groundcherry	Solanaceae	1
PHVI5	*Physalis virginiana*	Virginia groundcherry	Solanaceae	2
PLPA2	*Plantago patagonica*	woolly plantain	Plantaginaceae	3
POLYG4	*Polygonum*	knotweed	Polygonaceae	1
PODO4	*Polygonum douglasii*	Douglas' knotweed	Polygonaceae	1
PODE3	*Populus deltoides*	eastern cottonwood	Salicaceae	6
PSLA3	*Psoralidium lanceolatum*	lemon scurfpea	Fabaceae	4
PSTE5	*Psoralidium tenuiflorum*	slimflower scurfpea	Fabaceae	10
RACO3	*Ratibida columnifera*	upright prairie coneflower	Asteraceae	4
RATA	*Ratibida tagetes*	green prairie coneflower	Asteraceae	9
RAPH2	*Rayjacksonia phyllocephala*	camphor daisy	Asteraceae	3
RUMEX	*Rumex*	dock	Polygonaceae	1
RUVE2	*Rumex venosus*	veiny dock	Polygonaceae	0
SATR12	*Salsola tragus*	prickly Russian thistle	Chenopodiaceae	3
SCPA	*Schedonnardus paniculatus*	tumblegrass	Poaceae	1

PLANTS Code	Latin Name	Common Name	Family Name	Frequency within plots
SCSC	*Schizachyrium scoparium*	little bluestem	Poaceae	0
SCAC	*Schoenoplectus acutus*	hardstem bulrush	Cyperaceae	1
SCPU10	*Schoenoplectus pungens*	common threesquare	Cyperaceae	4
SESP3	*Senecio spartioides*	broomlike ragwort	Asteraceae	3
SOLAN	*Solanum*	nightshade	Solanaceae	0
SOGI	*Solidago gigantea*	giant goldenrod	Asteraceae	1
SONU2	*Sorghastrum nutans*	Indiangrass	Poaceae	0
SPPE	*Spartina pectinata*	prairie cordgrass	Poaceae	1
SPCO	*Sphaeralcea coccinea*	scarlet globemallow	Malvaceae	9
SPPO	*Spirodela polyrrhiza*	common duckmeat	Lemnaceae	0
SPAI	*Sporobolus airoides*	alkali sacaton	Poaceae	11
SPCR	*Sporobolus cryptandrus*	sand dropseed	Poaceae	19
STLE6	*Strophostyles leiosperma*	slickseed fuzzybean	Fabaceae	1
SYFA	*Symphyotrichum falcatum*	white prairie aster	Asteraceae	8
TAPA3	*Talinum parviflorum*	sunbright	Portulacaceae	0
TARA	*Tamarix ramosissima*	saltcedar	Tamaricaceae	2
THME	*Thelesperma megapotamicum*	Hopi tea greenthread	Asteraceae	2
TRTE	*Tribulus terrestris*	puncturevine	Zygophyllaceae	0
TYAN	*Typha angustifolia*	narrowleaf cattail	Typhaceae	1
VUOC	*Vulpia octoflora*	sixweeks fescue	Poaceae	0
XAST	*Xanthium strumarium*	rough cocklebur	Asteraceae	1
YUGL	*Yucca glauca*	soapweed yucca	Agavaceae	6

Appendix E. Photo Interpretation Mapping Conventions and Visual Key.

Sand Creek Massacre National Historic Site - Map Units

This appendix provides photographs and maps for each map unit at SAND. Included are:

- Descriptions of the link between each map unit and the NVC;
- Lists of common species found in each map unit;
- Ground photos image for each map unit;
- Visual examples of each map unit within the site with aerial photographs and delineated overlays;
- Describe the spatial characteristics of each map unit;

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CEGL002176—*Artemisia filifolia / Bouteloua gracilis* Shrubland 85

CEGL001756—*Bouteloua gracilis – Buchloe dactyloides* Herbaceous Vegetation 86

CEGL005024—*Populus deltoides / Pascopyrum smithii – Panicum virgatum* Woodland 87

CEGL001587—*Schoenoplectus pungens* Herbaceous Vegetation 88

CEGL001687—*Sporobolus airoides – Distichlis spicata* Herbaceous Vegetation 89

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Association Map Unit:

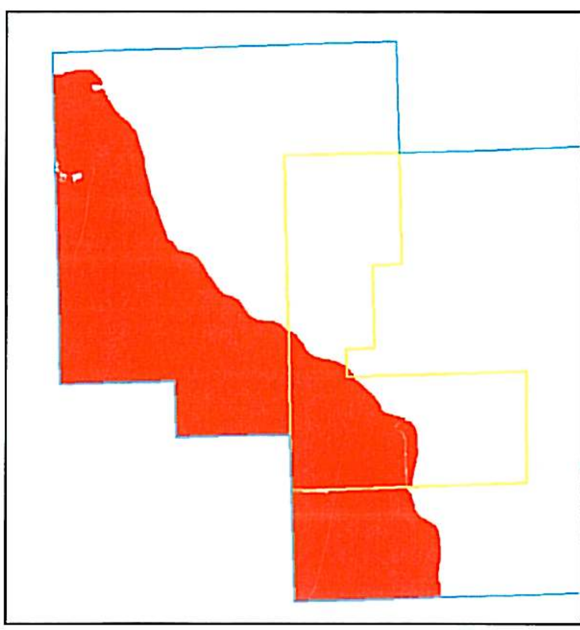
CEGL001459—*Artemisia filifolia / Andropogon hallii* Shrubland

Sand Sagebrush / Sand Bluestem Shrubland

Alliance: A.816. *Artemisia filifolia* (Sand Sagebrush) Shrubland Alliance

Common species:
Artemisia filifolia
Andropogon hallii
Bouteloua curtipendula
Calamovilfa longifolia
Bouteloua gracilis
Ambrosia psilostachya
Psoralidium tenuiflorum
Psoralidium lanceolatum
Erigeron bellidiastrum
Liatris punctata
Dalea cylindriceps
Helianthus petiolaris
Eriogonum annuum

Description:
This type occurs on the sandhills to the south and west of Big Sandy Creek and was mapped from field observations and plot data. The aerial photo signature is mottled grayish green with rough texture from *Artemisia filifolia* shrubs. The irregular ground surface shows hillocks (lighter) and swales (darker) at a landscape scale and greater amounts of bare ground are visible. Swales often had more annuals, but the composition differed between field seasons. The ecotone with *Artemisia filifolia / Bouteloua gracilis* Shrubland was mapped using a digital elevation model to identify the toeslope above the riparian terraces.



Association Map Unit:

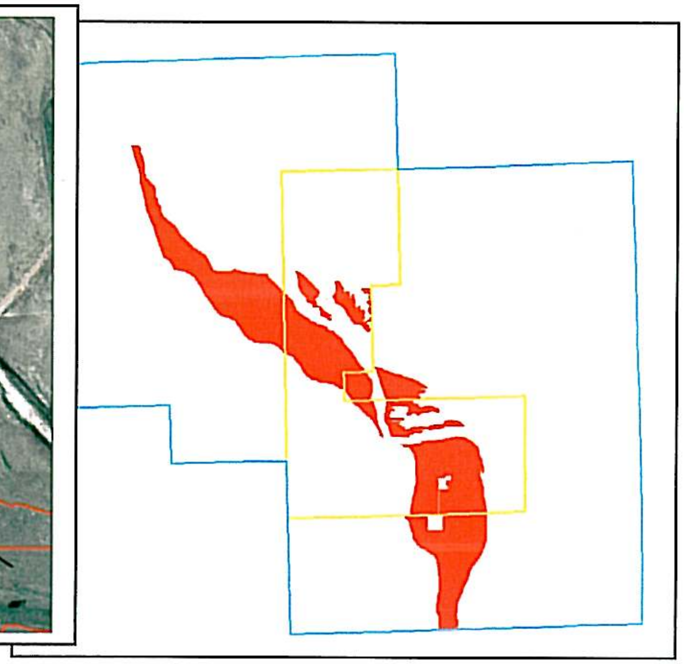
CEGL002176—*Artemisia filifolia / Bouteloua gracilis* Shrubland

Sand Sagebrush / Blue Grama Shrubland

Alliance: A.816. *Artemisia filifolia* (Sand Sagebrush) Shrubland Alliance

Common species:
Artemisia filifolia
Bouteloua gracilis
Sporobolus cryptandrus
Machaeranthera pinnatifida
Evolvulus nuttallianus
Cirsium ochrocentrum
Conyza canadensis
Sphaeralcea coccinea

Description:
This type occurs on terraces of Big Sandy Creek. The type was mapped from field observations and plot data. The aerial photo signature is grayish green with more rough texture from *Artemisia filifolia* shrubs. In places on the terraces it forms a mosaic with *Bouteloua gracilis – Buchloe dactyloides* Herbaceous Vegetation, but is distinguished by the presence of shrubs and a slightly more yellowish tint where shrubs are lacking. The ecotone with *Artemisia filifolia / Andropogon hallii* Shrubland was mapped using a digital elevation model to identify the toeslope above the riparian terraces.



Association Map Unit:

CEGL001756—*Bouteloua gracilis – Buchloe dactyloides* Herbaceous Vegetation

Blue Grama – Buffalograss Herbaceous Vegetation

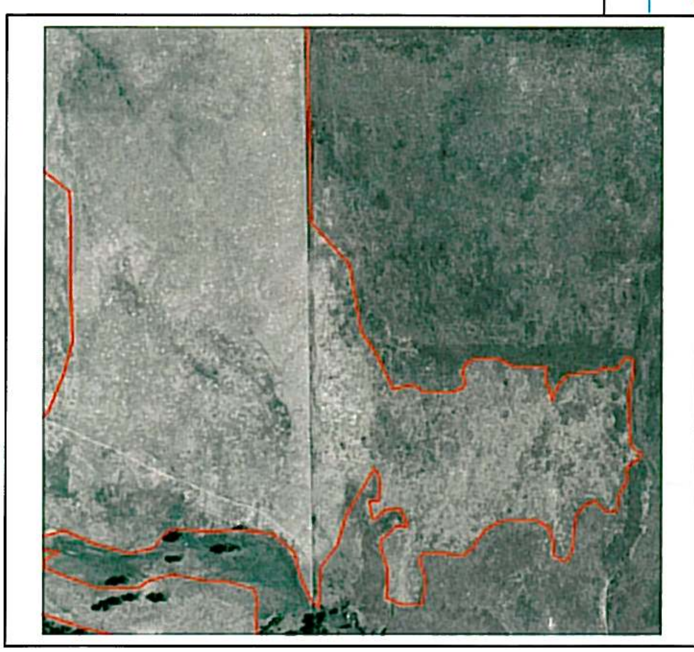
Alliance: A.1282 *Bouteloua gracilis* (Blue Grama) Herbaceous Alliance

Common species:

Bouteloua gracilis
Buchloe dactyloides
Sporobolus cryptandrus
Monroa squarrosa
Muhlenbergia torreyi
Muhlenbergia arenicola
Callirhoe involucrata
Sphaeralcea coccinea
Oxytropis sericea
Psoralidium tenuiflorum
Mirabilis glabra
Opuntia polyacantha

Description:

This type occurs on the level benches plains and on the terraces to the north and east of Big Sandy Creek. The aerial photo signature is a mottled light green to yellowish-green. It is often more yellow where there is greater *Buchloe dactyloides*. Prairie dog burrows are often evident as small white dots. On the stream terraces, the type forms a mosaic with *Artemisia filifolia / Bouteloua gracilis* Shrubland and forms an ecotone with *Sporobolus airoides – Distichlis spicata* Herbaceous Vegetation.



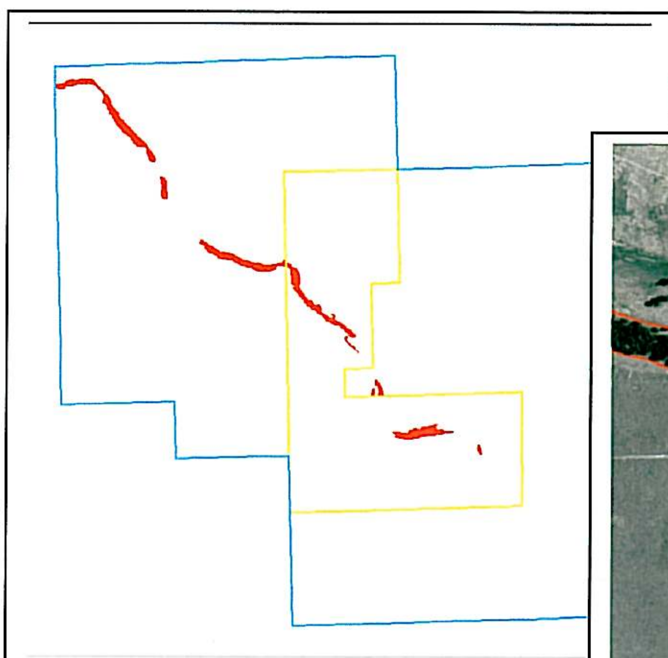
Association Map Unit:

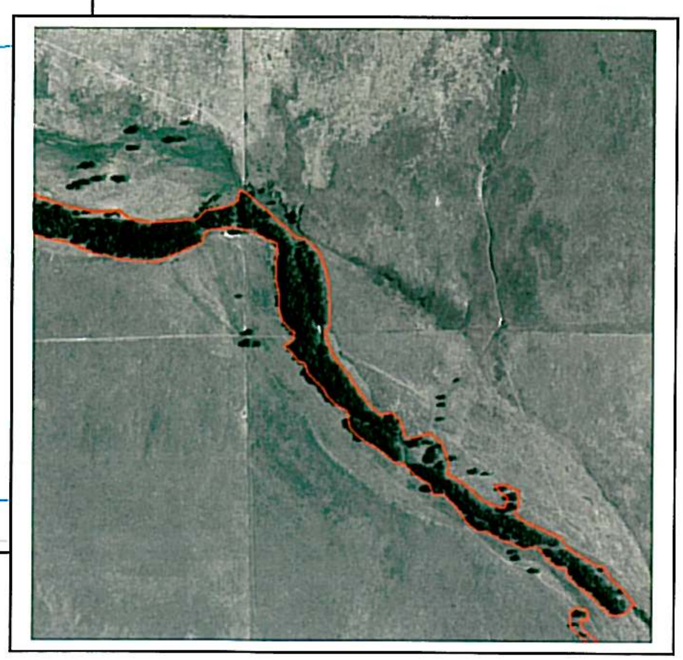
CEGL005024—*Populus deltoides / Pascopyrum smithii – Panicum virgatum* Woodland
Cottonwood / Western Wheatgrass - Switchgrass Woodland

Alliance: A.636 *Populus deltoides* (Eastern Cottonwood) Temporarily Flooded Woodland Alliance

Common species:
Populus deltoides
Panicum virgatum
Pascopyrum smithii
Elymus canadensis
Buchloe dactyloides
Ambrosia psilostachya
Asclepias subverticillata
Ratibida columnifera

Description:
This type is the only woodland association at SAND. It occurs along Big Sandy Creek although small patches occur away from the channel. The aerial photo signature shows dark green trees (*Populus deltoides*). Certain isolated individuals that were above the stream terraces were not always included if they did not appear to form a canopy.





Association Map Unit:

CEGL001587—*Schoenoplectus pungens* Herbaceous Vegetation

Common Threesquare Herbaceous Vegetation

Alliance: A.1433 *Schoenoplectus pungens* (Common Threesquare) Semipermanently Flooded Herbaceous Alliance

Common species:
Schoenoplectus pungens
Schoenoplectus acutus
Typha angustifolia
Muhlenbergia asperifolia

Description:
This type occurs along mesic to wet portions of the braided riparian channel in long, narrow strip. The aerial photo signature is very dark green to blackish green. This type most often forms a mosaic with *Sporobolous airoides – Distichlis spicata* Herbaceous Vegetation, which has a uniform green to smooth yellow-green color in the riparian corridor.

Association Map Unit:

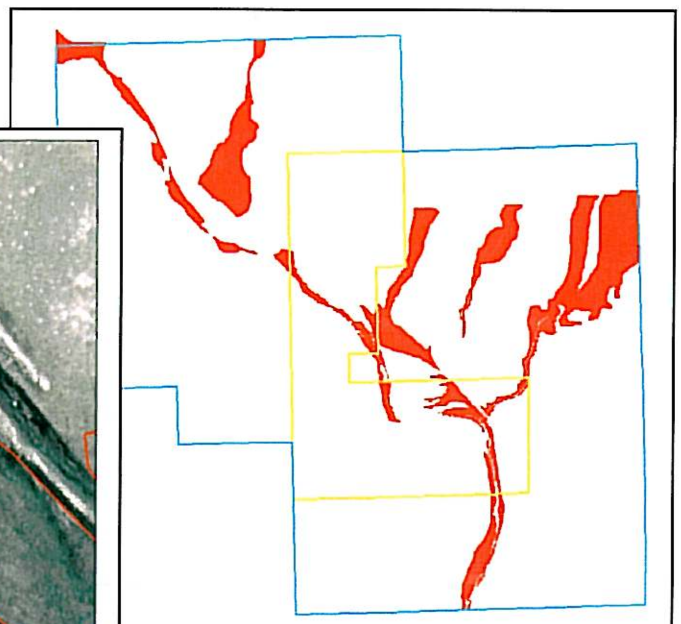
CEGL001687—*Sporobolus airoides – Distichlis spicata* Herbaceous Vegetation

Alkali Sacaton - Saltgrass Herbaceous Vegetation

Alliance: A.1331 *Sporobolus airoides* (Alkali Sacaton) Intermittently Flooded Herbaceous Alliance

Common species:
Sporobolus airoides
Distichlis spicata
Panicum obtusum
Muhlenbergia asperifolia
Asclepias subverticillata
Ratibida tagetes
Callirhoe involucrata

Description:
This type occurs in the braided riparian corridor of the Big Sandy and its tributaries. It occurs on the stream terraces adjacent to and above the *Populus deltoides* woodland along the main channel and it occupies the sloped sides of the tributaries that flow into Big Sandy Creek. The aerial photo signature is smooth green to yellowish green. Distinction of the ecotone with *Bouteloua gracilis – Buchloe dactyloides* Herbaceous Vegetation is difficult on this imagery, but the shortgrass prairie association tends to have a more brownish yellow in its yellowish green tint.



Map Unit: Agriculture

Alliance: none; park special map unit

Common species:
Winter wheat
Sunflower
Sorghum

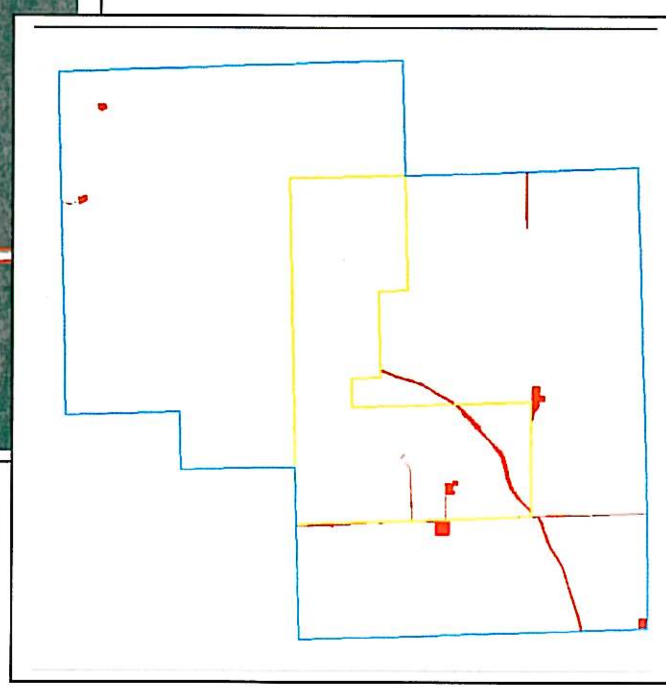
Description : This map unit reflects plowed agricultural fields, both planted and fallow.

Map Unit: Development

Alliance: none; park special map unit

Common Species:
Ulmus pumila
Celtis laevigata
Populus deltoides
Poa pratensis

Description:
This map unit reflects anthropogenic infrastructure and includes roads (wider than 12m), homesteads and associated infrastructure, and the Chivington Ditch.

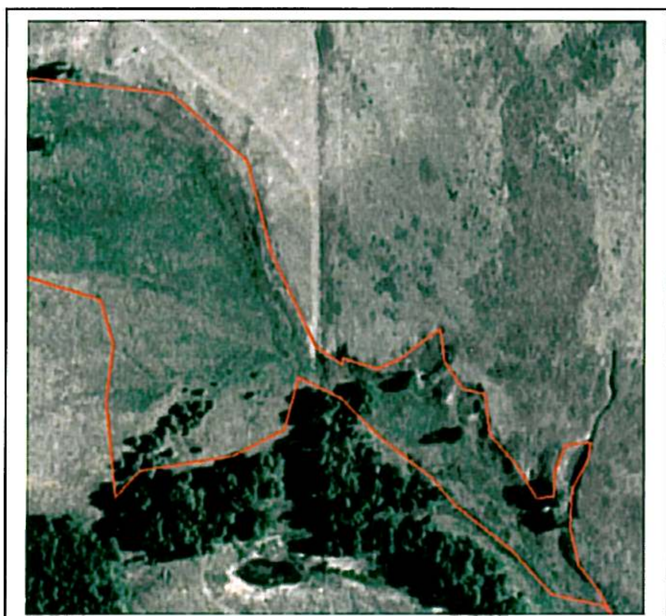


Map Unit: Disturbed

Alliance: none; park special map unit

Description:

This map unit reflects anthropogenic activity outside of development areas. These are areas dominated by non-native weedy species like *Bassia (=Kochia) scoparia* and *Salsola australis*, among others. These areas often occur where *Tamarix ramosissima* reduction and removal efforts occurred and where large machinery used to reduce *Salsola* tumbleweeds was used. The aerial photo signature is a creamy green of *Kochia*.

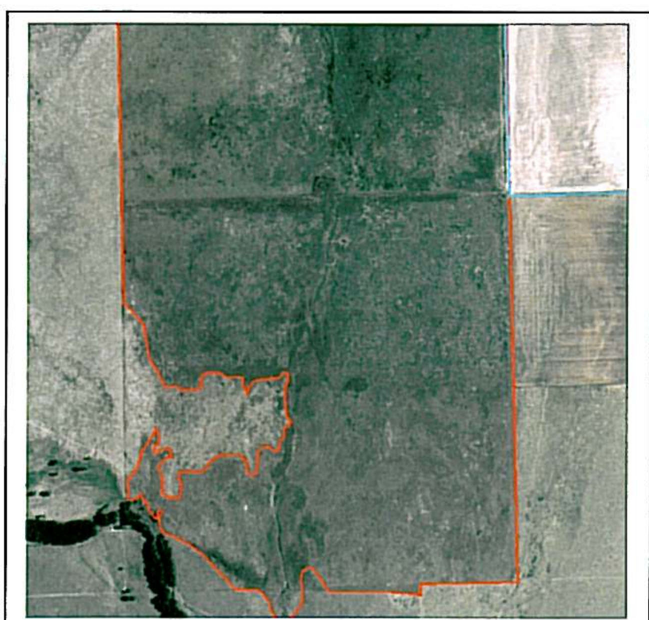


Map Unit: Reclaimed Agricultural Land

Alliance: none; park special map unit

Common species:
Bouteloua gracilis
Bouteloua curtipendula
Sporobolus cryptandrus
Panicum virgatum
Sphaeralcea coccinea
Lygodesmia juncea

Description:
This type occurs in primarily in the north-central portion of the authorized SAND boundary with additional areas on the east side. It is always adjacent to plowed agricultural fields. The aerial photo signature is a more brownish or tan green relative to more yellowish green and lighter green of the surrounding shortgrass prairie. The area has mottles of dark green, which reflect local weed infestations of *Salsola* or *Kochia.*



Appendix F. Contingency tables for each fuzzy set level of accuracy.

Page

Fuzzy level 5 – Binary Accuracy 96

Fuzzy level 4 – Acceptable Accuracy 97

Fuzzy level 3 – Reasonable Accuracy 98

Key to Map Class Codes:

1. Sand Sagebrush / Sand Bluestem Shrubland
2. Sand Sagebrush / Blue Grama Shrubland
3. Blue Grama - Buffalograss Herbaceous Vegetation
4. Development
5. Disturbed
6. Plains Cottonwood / Western Wheatgrass - Switchgrass Woodland
7. Black-tailed Prairie Dog Town Grassland Complex
8. Reclaimed Agricultural Land
9. Bulrush Wet Meadow
10. Alkali Sacaton – Inland Saltgrass Herbaceous Vegetation
11. Broadleaf Cattail Marsh

Fuzzy level 5 – Binary Accuracy

Reference data (from AA plots) in columns, classification data (from map polygons) in rows. C.I.=Confidence Interval.

Map Class Code	1	2	3	6	7	8	9	10	SUM	User Accuracy	+/- 90% C.I.	Map Proportion
1	16	4	0	0	0	0	0	0	20	80%	15%	0.2806
2	2	18	0	0	0	0	0	0	20	90%	11%	0.2379
3	0	5	6	0	7	0	0	1	19	32%	18%	0.0848
6	0	1	0	5	0	0	0	0	6	83%	25%	0.0236
7	0	0	0	0	20	0	0	0	20	100%	0%	0.0637
8	0	3	0	0	0	18	0	0	21	86%	13%	0.2385
9	0	0	0	0	0	0	4	0	4	100%	0%	0.0042
10	0	2	0	0	0	0	3	15	20	75%	16%	0.0667
SUM	18	33	6	5	27	18	7	16	130			
Producer Accuracy	90%	63%	100%	100%	67%	100%	30%	92%				
+/- 90% C.I.	8%	9%	0%	0%	14%	0%	28%	16%				

Overall Accuracy = 81% (75%-86%)
Kappa Value = 76%

Fuzzy level 4 – Acceptable Accuracy
Reference data (from AA plots) in columns, Classification data (from map polygons) in rows.
C.I.=Confidence Interval.

Map Class Code	1	2	3	6	7	8	9	10	SUM	User Accuracy	+/- 90% C.I.	Map Proportion
1	16	4	0	0	0	0	0	0	20	80%	15%	0.2806
2	2	18	0	0	0	0	0	0	20	90%	11%	0.2379
3	0	3	13	0	2	0	0	1	19	68%	18%	0.0848
6	0	0	0	6	0	0	0	0	6	100%	0%	0.0236
7	0	0	0	0	20	0	0	0	20	100%	0%	0.0637
8	0	3	0	0	0	18	0	0	21	86%	13%	0.2385
9	0	0	0	0	0	0	4	0	4	100%	0%	0.0042
10	0	2	0	0	0	0	1	17	20	85%	13%	0.0667
SUM	18	30	13	6	22	18	5	18	130			
Producer Accuracy	90%	66%	100%	100%	88%	100%	56%	93%	Overall Accuracy = 85% (80%-90%) Kappa Value = 81%			
+/- 90% C.I.	8%	9%	0%	0%	16%	0%	60%	14%				

Fuzzy level 3 – Reasonable Accuracy

Reference data (from AA plots) in columns, Classification data (from map polygons) in rows. C.I.=Confidence Interval.

Map Class Code	1	2	3	6	7	8	9	10	SUM	User Accuracy	+/- 90% C.I.	Map Proportion
1	20	0	0	0	0	0	0	0	20	100%	0%	0.2806
2	0	20	0	0	0	0	0	0	20	100%	0%	0.2379
3	0	3	16	0	0	0	0	0	19	84%	14%	0.0848
6	0	0	0	6	0	0	0	0	6	100%	0%	0.0236
7	0	0	0	0	20	0	0	0	20	100%	0%	0.0637
8	0	3	0	0	0	18	0	0	21	86%	13%	0.2385
9	0	0	0	0	0	0	4	0	4	100%	0%	0.0042
10	0	2	0	0	0	0	1	17	20	85%	13%	0.0667
SUM	20	28	16	6	20	18	5	17	130			
Producer Accuracy	100%	81%	100%	100%	100%	100%	56%	100%	Overall Accuracy = 94% (91%-98%)			
+/- 90% C.I.	0%	9%	0%	0%	0%	0%	60%	0%	Kappa Value = 93%			

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS D-9, March 2007

National Park Service
U.S. Department of the Interior

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